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EPA Program Status Report: Oil Shale 1980 Update

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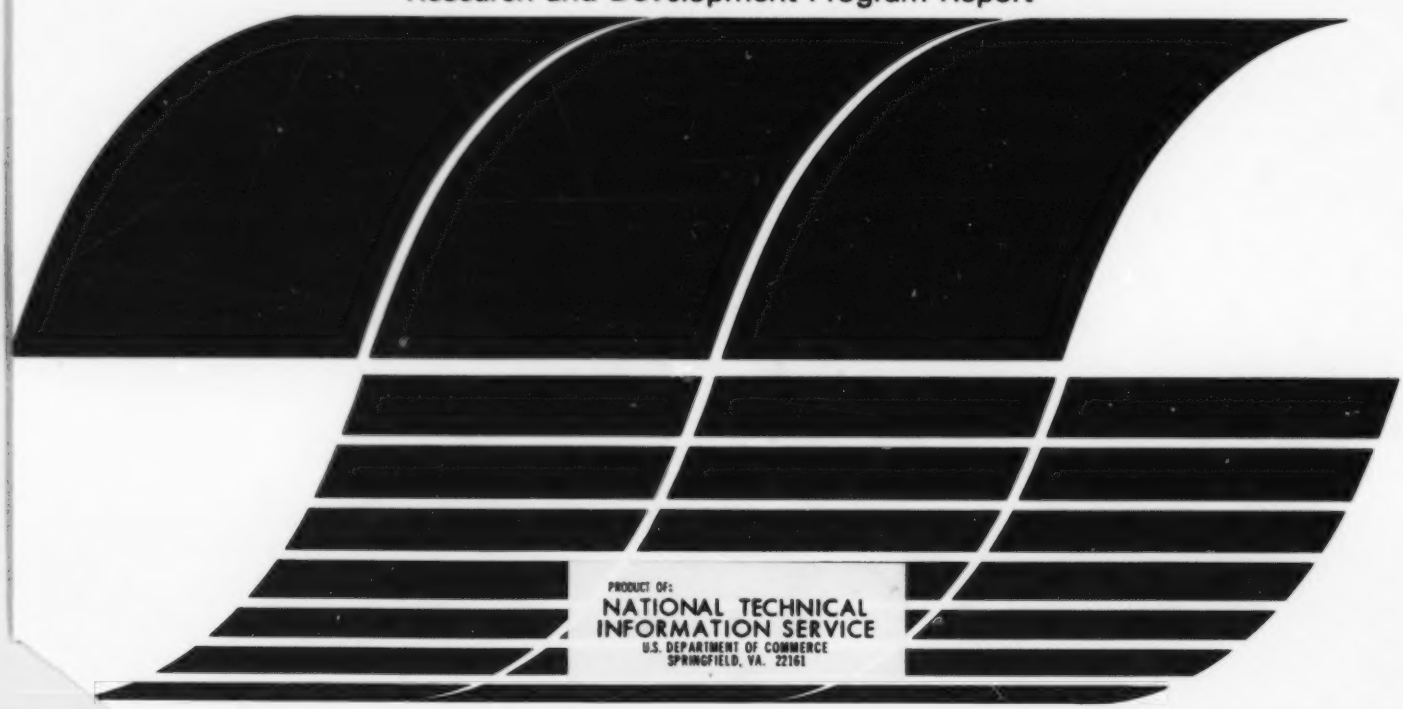
Program Status Report

Oil Shale 1980 Update

Interagency Energy-Environment
Research and Development Program Report



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5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
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This report has been assigned to the INTERAGENCY ENERGY-ENVIRONMENT RESEARCH AND DEVELOPMENT series. Reports in this series result from the effort funded under the 17-agency Federal Energy/Environment Research and Development Program. These studies relate to EPA's mission to protect the public health and welfare from adverse effects of pollutants associated with energy systems. The goal of the Program is to assure the rapid development of domestic energy supplies in an environmentally-compatible manner by providing the necessary environmental data and control technology. Investigations include analyses of the transport of energy-related pollutants and their health and ecological effects; assessments of, and development of, control technologies for energy systems; and integrated assessments of a wide range of energy-related environmental issues.

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16. ABSTRACT

This report provides the reader with an overview of current EPA oil shale research and development (R & D) and projects funded by EPA monies passed-through to other Federal agencies under the five year old, 17-agency Interagency Energy/Environment R & D Program. Chapter 1 introduces the purpose, background, and rationale of EPA's efforts; Chapter 2 summarizes EPA program goals in these areas: overall assessments, processing extraction and handling, energy-related processes and effects and end use; Chapter 3 presents the scope of work and status for all current projects. A table summarizes these projects, listing project, title, project contact, duration, contractor, and funding. The following appendices are included: World Resources and Development History, Glossary of Terms, Glossary of Abbreviations, General Bibliography on Oil Shale.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS			b. IDENTIFIERS/OPEN ENDED TERMS		c. COSATI Field/Group
Air pollution	Funding	Oil shale	Anvil Points	Pollution Control Guidance Document	04B 06B 68C
Air quality	Ground water	Pollution	Colorado	Research & Development	06A 06T 68D
Aquifers	Health effects	Processing	Control Technology	TOSCO	06C 08H 68G
Ecology	Hydrology	Shale oil	Environmental Assessment	Uinta Basin	06E 081 680
Extraction and handling	In situ	Spent shale	Integrated Assessment	Utah	06F 13B 97A
Fossil fuels	Land reclamation	Synthetic fuels	Paraho	World Resources	06J 480 97F
Fugitive dust	Mining	Water pollution	Piceance Basin	Wyoming	68A
	Monitoring	Water quality			

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FOREWORD

The U.S. Environmental Protection Agency is involved in oil shale research and development through projects for which it provides funds, and by staying abreast of projects funded by other governmental and industrial sources. Research provides data for defining ecological and health effects and developing cost-effective control technology that can be used by government and industry to minimize degradation of the environment.

This report presents the status of current EPA projects related to oil shale research and development.

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The EPA Oil Shale Research Group wishes to thank Jeannette King and Eleanor Swanson of the Denver Research Institute for accepting the challenge to publish this document, based on the 1979 publication plus input obtained from more than three dozen contributors.

We wish to acknowledge with thanks the efforts of Ed Bates, IERL-Ci, who served as project officer and coordinator.

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EXECUTIVE SUMMARY

EPA's Office of Research and Development has been reorganized and divided into the Office of Monitoring and Technical Support, Office of Environmental Engineering and Technology, Office of Environmental Processes and Effects Research and the Office of Health Research. All of these offices are actively involved in oil shale research with a collective budget of approximately $5 million in fiscal 1980.

Within EPA several separate laboratories conduct or contract oil shale-related environmental studies. The Office of Environmental Processes and Effects acts as coordinator for the Interagency Program. The Office of Environmental Engineering and Technology (OEET) has contracts work in the area of overall assessments and control technology. The Industrial Environmental Research Laboratory in Cincinnati (IERL-CI) funds and manages research on overall assessments, extraction and handling, processing and management and control of all pollutants. Research laboratories in Ada, Oklahoma; Athens, Georgia; Duluth, Minnesota; Las Vegas, Nevada; and Research Triangle Park, North Carolina conduct research studies in the processes and effects area. Shale oil product (end use) studies are managed and funded by both the Industrial Environmental Research Laboratory at Research Triangle Park (IERL-RTP) and Ann Arbor (Michigan) Emission Control Technology Division (ECTD) of the Office of Air, Noise and Radiation.

Specific objectives of the EPA Oil Shale Program are two-fold: first, the program is to support the regulatory goals of the Agency; second, the research is to be directed towards ensuring that the development of any oil shale industry will be accomplished in the most environmentally acceptable manner reasonably possible. To meet these objectives, EPA is continuing to assess the research needs and environmental concerns expressed by the Department of Energy (DOE) and the oil shale industry.

EPA is active in many areas of oil shale research and development, and closely monitors projects of other Federal agencies to prevent duplication and to encourage programs which contribute to the development of the oil shale industry.

EPA Oil Shale Research may be divided into five subject areas: Overall Assessments, Extraction and Handling, Processing, Energy-Related Processes and Effects, and End Use. The Energy-Related Processes and Effects program has four important subdivisions: health effects, ecological effects, measurement and monitoring, and environmental transport studies.

The total budget supporting the EPA Oil Shale Program in Fiscal Year (FY 80) was $5,795,588 compared to $6,091,073 in FY 79. An increase in funds for the program can be expected if the commercialization of our nation's oil shale reserves is given a primary role in the National Energy Plan. Agencies participating in the EPA Oil Shale Program include: U.S. Department of Energy, U.S. Geological Survey, National Bureau of Standards, U.S. Department of Agriculture, the Department of Navy and the National Institute of Environmental Health Sciences.

Specific objectives of the EPA Oil Shale Program are 1) to support the regulatory goals of the Agency, and 2) to direct research ensuring an environmentally safe oil shale industry. To meet these objectives, EPA continues to assess research needs and environmental concerns expressed by the U.S. Department of Energy (DOE) and the oil shale industry.

Research attempting to solve problems identified by the DOE's Laramie Energy Technology Center, and the active developers, is underway. The EPA Office of Research and Development focuses in part on problems defined by the Laramie Center, because Laramie is responsible, within DOE, for managing and implementing the national effort for oil shale development.

Major accomplishments over the past year have included: development of the document Environmental Perspectives on the Emerging Oil Shale Industry, which presents general information on oil shale pollution problems and pollution control; initiation of work on a pollution control guidance document which will discuss the applicability, performance and costs of pollution control technology available for the oil shale industry; and presentation of a forum and meetings with industry to provide for an exchange of information between EPA and industry on pollution control aspects of oil shale development.

1.0 INTRODUCTION

This report provides an overview of current oil shale research and development (R&D) efforts being carried out by the Environmental Protection Agency (EPA), or funded by EPA money passed-through to other federal agencies under the Interagency Energy/Environment R&D Program. This chapter introduces the background and rationale behind EPA's efforts. Chapter 2 discusses EPA's program goals and fiscal year (FY) 1979 and 1980 program funding. The scope of work for ongoing projects and a table summarizing these efforts are presented in Chapter 3.

1.1 Background

Since its establishment in 1970, EPA has been involved in energy-related environmental research efforts, including the development of pollution control technologies designed to eliminate the adverse effects that are often by-products of energy conversion. Oil Shale Research within EPA is conducted by the Office of Research & Development (ORD).

Through its programs, ORD strives to coordinate the efforts of all Agency research related to the oil shale industry. The goals of the seventeen-agency group working with ORD are protecting the environment through all phases of energy production and use, while also developing cost-effective pollution control technologies.

The EPA Oil Shale Research Group, consisting of Agency personnel actively involved in oil shale research, was established to encourage coordination of oil shale research activities and distribution of information within the Agency.

When the President announced the Oil Import Reduction Program and subsequently proposed the Energy Mobilization Board and the Synfuel Development Corporation, the Administrator of EPA responded by establishing an Alternate Fuels Group. This group has representation from every major program office that could have an impact on the synthetic fuels industry. The purpose of this group is to establish Agency policy for the synthetic fuels industry and to see that policy is implemented consistently throughout the Agency. The Administrator also developed a group to assist in devising efficient Agency permitting procedures for synthetic fuel development.

Within the Alternate Fuels Group, four working groups have been established. One of these is the newly formed Oil Shale Working Group, (OSWG). The OSWG should not be confused with the Oil Shale Research Group previously discussed The OSWG currently has four major objectives: 1) coordinating the development of an Oil Shale Pollution Control Guidance Document; 2) developing a five year Oil Shale Research Plan indicating major activities the Agency intends to accomplish, the estimated time required for each activity, and the part of the Agency responsible for each activity. (This plan is being coordinated with the Departments of Energy and Interior); 3) developing an Environmental Issues Paper which will serve as a fact book specifically related to the development of the synthetic fuels industry; 4) overseeing and coordinating the development of environmental standards and guidelines for the synthetic fuels industry. The Oil Shale Working Group is represented by OR&D, each major program office, and the Denver Regional Office.

The cooperative efforts between the Office of Research and Development and the oil shale programs administered by Region VIII typify the manner in which the Agency's programs are coordinated. The majority of the oil shale activities in this country take place in Region VIII. That region participates in planning and implementing the Research Program in addition to processing permits for oil shale facilities and serving as a communication center for many federal, state, and industry personnel.

1.2 Rationale

Our cheap and abundant energy supplies are rapidly being depleted. Domestic reserves of oil and natural gas have been declining since 1970, and imported oil and gas are growing increasingly more expensive. U.S. vulnerability to supply interruption has also increased. By the mid-1980s, the U.S. could be vying for scarce oil against its allies and other consuming nations, causing even greater price increases and demands on the world oil supply.

In anticipation of these circumstances, the U.S. must significantly reduce its reliance on imported oil and gas, and make greater use of domestic energy resources. The present energy mix consists of crude

oil, natural gas, coal, hydroelectric power, and some geothermal power, but considerable R&D activity now focuses on other energy sources such as solar, tar sands, synthetic oil and gas from coal and oil shale.

The principal known oil shale deposits of the U.S. are shown in Figure 1. The richest of the deposits is the Green River Formation of Colorado, Utah, and Wyoming. This region contains the largest single known concentration of hydrocarbons in the world. If only that portion of the Green River Formation containing the equivalent of 25 gallons (or more) of oil per ton of shale were mined, it has been estimated that the shale oil in-place would amount to approximately 731 billion barrels of oil.

Because western oil shale is a domestic energy resource of considerable magnitude, the availability of large quantities of crude shale oil for refining products such as gasoline, diesel, and jet fuels could substantially expand the U.S. energy supply. Current R&D work is oriented toward finding an economically and environmentally practical way of producing shale oil and bringing it to market.

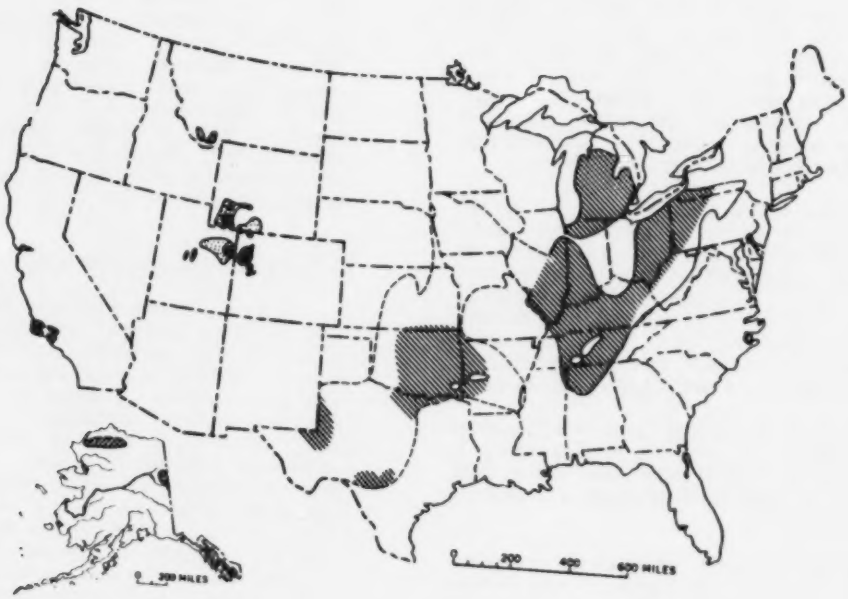

Figure 1.

PRINCIPAL OIL SHALE DEPOSITS OF THE U.S.

Explanation

Tertiary deposits: Green River Formation in Colorado, Utah, and Wyoming; Monterey Formation, California; middle Tertiary deposits in Montana. Black areas are known high-grade deposits.

Mesozoic deposits: Marine shale in Alaska.

Permian deposits: Phosphoria Formation, Montana.

Devonian and Mississippian deposits (resource estimates included for hachured areas only). Boundary dashed where concealed or where location is uncertain.

2.0 PROGRAM OVERVIEW

EPA studies on developing oil shale and bringing it into commercial use are providing information on health and ecological effects of pollutants created by oil shale extraction and processing, and on technological methods that can be used to control the release of those pollutants. Various programs are also assessing the environmental impact of the use of fuels refined from shale oil. These efforts are principally supported by funds from the seventeen-agency Federal Interagency Energy/Environment R&D Program.

Studies under this program are carrying out EPA's mission to protect the public health and welfare from adverse effects of pollutants associated with energy production and use. The goal of the program is to assure the rapid development of domestic energy supplies, and at the same time, maintain environmental safety by providing the necessary data and control technology.

Through managing and coordinating the program, as well as implementing a portion of the effort with the above goal as its focus, EPA is developing a sound oil shale industry.

EPA's oil shale program is administered by the Office of Research and Development. The overall effort may be divided into five subject areas:

Overall Assessments

Extraction and Handling

Processing

Energy-Related Processes and Effects

End Use

The remainder of this chapter discusses programs in each of these areas (see Table 1, Program Status Summary for EPA contacts, contractors and term of programs). Figure 2 shows EPA funding and pass-through funding for the oil shale program for FY's 79-80. Chapter 3 provides details on each of the projects mentioned in this overview.

2.1 Overall Assessments

The overall assessment program was established to define and evaluate the various environmental and socioeconomic effects that result from energy extraction, processing, transportation, conversion, and end use activities. Objectives of the program include: identifying energy supply and conversion alternatives; evaluating cost/risk/benefit relationships in energy production, conservation, and pollution control; assisting the nation in selecting optimized policies for attaining energy and environmental quality goals; and identifying critical gaps in current energy-related research programs, and other priority research topics, which must be addressed to support direct EPA responsibilities.

2.2 Extraction and Handling

EPA's program for oil shale extraction and handling attempts to assess potential environmental problems and develop resource handling and control methods for in situ and surface oil shale extraction and land reclamation. If damaged, the semiarid and arid oil shale areas of the West will be extremely difficult to restore. This program is working to define environmentally acceptable practices for oil shale extraction. Studies underway are assessing not only the potential environmental impact on air and water, but also methods for spent shale disposal and revegetation of spent shales.

Work being performed involves assessing the potential environmental impact upon air and water resources from the extraction and handling of oil shale resources. Also included are studies of disposal and revegetation of spent oil shales.

2.3 Processing

The EPA program for processing seeks to ensure that future large-scale commercial applications of oil shale processing, combustion, and use can be constructed and operated within environmental guidelines. The program's approach includes environmental assessment, evaluation, and testing of a number of processes in order to define the best available control technology, prepare standards-of-practice manuals, and support standards-setting efforts.

The overall objective of this program is to define environmental problems early in the process development phase and to

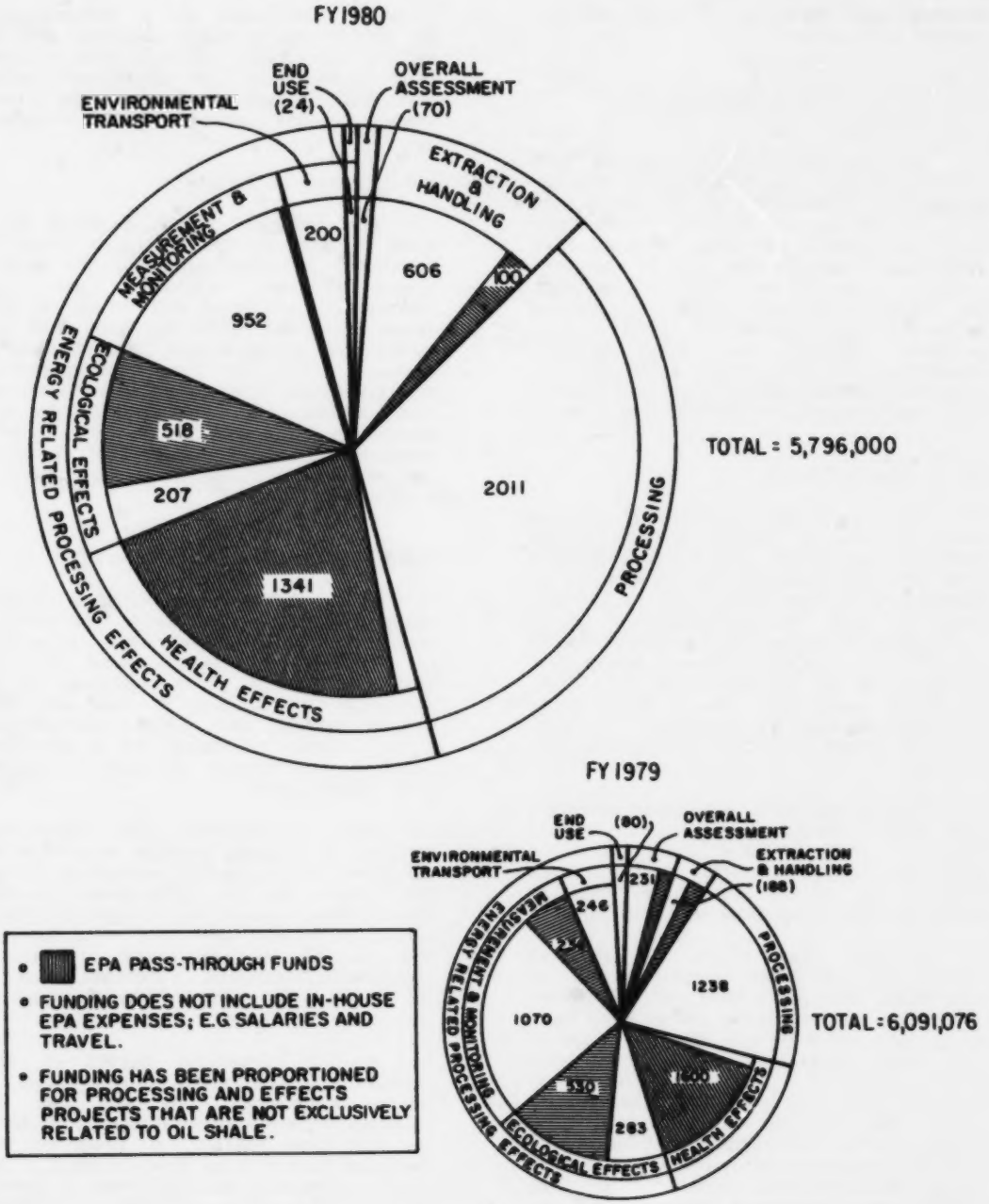

FIGURE 2
EPA OIL SHALE FY 1979 AND 1980 FUNDING SUMMARIES
(in thousands of dollars)

develop and implement effective pollution control technologies.

2.4 Energy-Related Processes and Effects

The energy-related processes and effects program is designed to identify mechanisms of transport in the environment and the effects on human, animal, and plant populations associated with energy-related activities. The goal of the program is to compile and evaluate information to support decisions protecting natural biota and human health and welfare. This program includes four areas directly involved in oil shale R&D: health effects, ecological effects, measurement and monitoring, and environmental transport processes.

2.4.1 Health Effects

The health effects research program seeks to identify hazards from pollutants released by various energy technologies. The program includes the development of bioassay and other techniques to measure hazards, and the application of these techniques to characterizing human health hazards. In relation to human health, the emphasis of the program is on the effects of agents which give rise to carcinogenesis, mutagenesis, teratogenesis, toxicity, and disorders of the cardiopulmonary system.

Various pollutants are being examined for their impacts on human health. Research efforts have confirmed that pollutants such as sulfur and nitrogen oxides and their atmospheric reaction products are detrimental to human health.

Another major effort has been to assess the potential health impacts of developing energy technologies. Although a number of preliminary assessments have been made, most data is from processes in the early stages of development, and standard-setting information must be derived from extrapolation of bench and pilot scale data to the commercialization stage. This developmental work also provides guidance to industry on anticipated environmental regulations so that sudden and expensive equipment alterations can be avoided.

Other work involves a number of testing methods that have been developed or refined by research supported by EPA. These efforts include new methods of identification through cytological, biochemical, and physiological indicators of the damages resulting from exposure to pollutants associated with energy development. By incorporating these methods into a testing hierarchy, EPA's health effects program has been able to efficiently allocate available research funds in the Interagency Energy/ Environment R&D Program.

2.4.2 Ecological Effects

The ecological effects research program is based on the results of research conducted in other areas of the Interagency Program. Various methods and instruments developed and refined in the measurement and monitoring areas, and the results of environmental transport processes studies, are used to characterize the ecosystem effects associated with oil shale development. Research efforts are determining the effects of organic and inorganic pollutants, thermal discharges, and complex effluents on soil and aquatic ecosystems.

2.4.3 Measurement and Monitoring

This research area involves detection, measurement, and monitoring of pollutants, and quality assurance testing to characterize ecosystem effects associated with oil shale development. The objectives are to accelerate development of new and improved sampling and analysis methods for energy-related pollutants and to identify, measure, and monitor effluents during oil shale development.

The measurement and monitoring program is defining baseline environmental conditions and analyzing impacts of energy development on the environment by the identification, measurement, and long-term monitoring of air, land, and water quality. The various research efforts investigate organic and inorganic pollutants, thermal discharges and complex effluents on water and land ecosystems.

Another important aspect of the measurement and monitoring program is quality assurance. The data that are collected on environmental pollutants must be valid and reliable, so programs are designed to guarantee data accuracy. The quality assurance activities seek to insure the use of a common, acceptable monitoring methodology so that data may be compared.

2.4.4 Environmental Transport Processes

The activities of this research area are closely related to research in measurement and monitoring, and ecological effects

research. In the environmental transport processes program, methods and tools are developed, tested, and applied to provide data for understanding transport and fate processes. Ecological effects studies investigate the effects of pollutants on organisms and their habitats. Environmental transport processes research studies energy-related pollutants in terms of mechanisms of dispersion from sites of production, transformations which occur subsequent to release, and ultimate accumulation in man, domesticated and wild animals and plants, and in nonliving material such as soil and sediments.

2.5 End Use

The end use studies focus on environmental problems which may result from the refining and combustion of shale oil. To date research has focused primarily on production of NO_x due to the high nitrogen content of the shale oil.

3.0 PROGRAM STATUS

3.1 Overall Assessments

3.1.1 Environmental Perspective on the Emerging Oil Shale Industry

The EPA Oil Shale Research Group is preparing a report entitled, Environmental Perspective on the Emerging Oil Shale Industry, which will provide environmental guidance for those involved in this emerging industry. The report is intended as a reference for regulators, developers, and others who are or will be involved with the oil shale industry. The report will be published in three volumes: an executive summary, the main report, and a volume of appendices.

This report will convey the EPA's understanding of and perspective on environmental aspects of oil shale development by providing a summary of available information on oil shale resources; a summary of major air, water, solid waste, health, and other environmental impacts; an analysis of potential pollution control technology; a guide for the sampling, analysis, and monitoring of emissions, effluents, and solid wastes from oil shale processes; suggestions for interim objectives for emissions, effluents and solid waste; and a summary of major retorting processes, emissions, and effluents.

3.1.2 EPA/Industry Forum

In 1979 the headquarters office of OEET and its Cincinnati Laboratory (IERL-Ci) continued their second effort to establish a closer working relationship between EPA and the industrial firms interested in developing oil from oil shale. The second EPA/Industry Forum on Oil Shale was held in August, 1979. Ninety-five persons representing the oil shale industry, EPA, DOE and other government agencies attended. A review of the Administrator's plans for the development of synthetic fuels was presented. It was disclosed that by 1990, we expect a capacity of at least 400,000 barrels per day from oil shale. The Agency described its mechanism for providing pollution control guidance to the industry and to Federal and State permit writers.

3.1.3 Who's Who in Oil Shale

The task of preparing the Who's Who in Oil Shale directory was undertaken for two reasons: to identify the scientists, engineers and managers in government and universities who are currently involved in activities relating to oil shale; and to provide a mechanism for encouraging communication between individuals in government and universities who are working in oil shale research, engineering and management.

In the last few years, interest in tapping this nation's vast oil shale resources has been growing steadily as the need for increased domestic supplies of energy becomes critical. The President, in his energy message (July 16, 1979), emphasized the importance of oil shale in his proposals for reducing dependence on foreign oil. Several major pieces of energy legislation are now under consideration by Congress: one, recently signed into law by the President, calls for the creation of an Energy Security Corporation to oversee and provide financial incentives for the establishment of a synthetic fuels industry. The number of people working toward this important goal has increased in all sectors of society. The intent of the directory's editors has been to encourage broad and productive communication between all who are working to create a successful oil shale industry.

This directory lists all people in government (federal, state and local) and universities involved in scientific, engineering and management activities related to oil shale development. It is divided into the following major sections:

- Glossary of Abbreviations
- Areas of Activity Index
- Organization Index
- Committee Index
- Location Index
- Publications Directory
- Federal, State and University Directory
- Local Government Directory
- Oil Shale Government/University Telephone Directory (detachable)

Further directories of this kind are planned on a yearly basis. The editors intend to include managers, engineers and scientists from the private sector in the next directory.

3.1.4 Oil Shale Symposium: Sampling, Analysis and Quality Assurance

This Symposium was held in Denver, Colorado, March 26-28, 1979, and brought

together scientists from a variety of disciplines who presented papers on methodologies for pollution analyses relevant to the oil shale industry. Communication and information exchange among academic, industrial and government researchers were prime objectives. Topics included: pollutants which can and should be characterized and quantified, media to be examined, health and ecological effects, sampling and analyses methods, quality assurance needs, future methodologies, reference materials and instrumentation development. The symposium provided an opportunity for participants to share and verify methods, collect data and exchange information; and promote the quality of ongoing research in oil shale development.

3.2 Extraction and Handling

Within the extraction and handling program are nine projects sponsored by EPA's Industrial Environmental Research Laboratory in Cincinnati (IERL-Ci). Five projects dealing with processed oil shale are underway at Colorado State University, Fort Collins. Two are assessing the environmental impact of raw mined oil shale leachates. Two projects investigate the effects of spent shale, its permeability and revegetation. Another CSU project studies the effects of oil shale development on water quality. The Lawrence Berkeley Laboratory, University of California, Berkeley, California, is analyzing trace element composition in two cores from the Naval Oil Shale Reserve. Science Applications, Inc., Lafayette, California, will assess air emissions from old oil shale waste sites. A project being conducted by the USDA using EPA pass-through funds is developing recommendations for revegetation following oil shale mining. At Davis Gulch, Colony will study moisture movement through TOSCO II processed shale.

Develop Recommendations, Guidelines and Criteria for Revegetation of Oil Shale Spoils on Semi-Arid Lands

The overall purpose of this project is to develop criteria for successful revegetation of processed oil shale on semi-arid lands. A cooperative agreement was developed with TOSCO whereby they would provide processed oil shale. Field studies are being conducted in western Colorado and eastern Utah where disposal of spoils will occur.

Among 10 species tested at Davis Gulch (Colorado) without leaching of salts the most successful species in descending order were: Atriplex canescens, Caragana arborescens, Kochia prostrata, Chrysothamnus nauseosus, Ephedra viridis, and Artemisia tridentata. All had survival percentages greater than 57 percent.

Covering processed shale with one foot of topsoil enabled a number of native perennials to become successfully established, including Oryzopsis hymenoides, Penstemon strictus, Achillea lanulosa, Artemisia tridentata, and Xanthocephalum sarothrae. These probably grew from seeds already in the topsoil.

Results at Sand Wash (Utah) show that without leaching of salts, 7 of 18 shrub species transplanted from containers will grow well in processed oil shale with or without irrigation the first year. At the end of the fourth growing season, 5 native shrub species and 2 introduced species were thriving under all conditions of cover ranging from 0 to 3 feet (0 to 0.914 m) deep over processed shale. A group of eight species showed very poor survival on the processed shale itself, but varying success where soil covered shale, depending upon the depth of covering. Height growth of these species increased with soil depth, at least to the 1-foot depth.

Water Quality Hydrology Affected by Oil Shale Development

Colorado State University is under a cooperative agreement from IERL-Ci to study the water quality of both surface and subsurface drainages in oil shale areas of Colorado, Wyoming, and Utah. Specific objectives of this study are: 1) to gather all available data pertinent to present and future assessment of water quality in the oil shale regions of the Upper Colorado River Basin; 2) to summarize and analyze these data in order to identify needs for additional data, and to develop procedures for assessing the impact on water quality management; and 3) to develop procedures for measuring quantity and quality of surface and subsurface runoff from processed shale residue and mine spoils, and to verify these procedures using existing large-scale volumetric lysimeters at Anvil Points, Colorado. Term of this project is from June 1975 to June 1980.

Vegetative Stabilization of Spent Oil Shale

Colorado State University is working under a grant from IERL-Ci to continue investigations of surface stability and salt movement in spent oil shales and soil-covered spent shales after a cover of native vegetation has been established by intensive treatments and then left under

natural conditions. Work under this project continues maintenance and observations on vegetation, moisture, salinity, runoff, and sediment yields on revegetation plots established in 1974 and 1975.

Three different spent oil shales--coarse-textured USBM, fine-textured TOSCO II, and coarse-textured Paraho Direct Mode--are being analyzed. Various soil treatment tests are included to study plant establishment on leached spent shale, soil cover over leached spent shale, soil cover over unleached spent shale, and soil with no spent shale.

Data collected includes general observations, runoff and sediment samples, soil moisture measurements, movement of salts in soil and shale profiles, maintenance of meteorological equipment, and vegetation analysis of species and groundcover. A final report is expected in 1981.

Laboratory Study of the Leaching and Permeability of Spent Oil Shale

Colorado State University is working under a cooperative agreement with IERL-Ci to determine the leaching characteristics of spent oil shale from several processes. The objectives are: 1) to determine the quality of leachate from spent oil shales from several retort processes, 2) to determine the change in leachate quality with pore volumes of water leached through the spent shale, 3) to determine the permeability of various spent shales compacted to increasing levels and under loading conditions simulating field disposal, 4) to compare leaching results from column leaching tests with results from the RCRA and other shaker type tests, and 5) to compare results from this laboratory study with information available from larger field tests. A final report will be available in 1982.

Trace Element Analysis on Cores from the Naval Oil Shale Reserves

Lawrence Berkeley Laboratory of the University of California is examining two core samples from the Naval Oil Shale Reserve for the presence of 45 elements including As, Se, Mo, B, F, Hg, Cd, and U. One hundred and eighty-five (185) composite samples will be prepared from core segments selected to include oil shale zones under consideration for commercial development. These samples will be analyzed using the neutron activation method, Zeeman atomic absorption spectroscopy, and other selected methods. X-ray fluorescence spectrometry will be used to validate the methods previously cited in the case of selected samples. Results can then be used to aid in selecting environmentally acceptable sites for in situ oil shale plants or in selecting zones for mining for surface retorting which would minimize environmental impacts. This project is cofunded by IERL-Ci, the U.S. Navy, and the Department of Energy. A final report should be available late in 1980.

Leaching Characteristics of Raw Surface Stored Oil Shale

Colorado State University is working under grant from IERL-Ci to determine the leaching characteristics of raw oil shale to discover potential impacts on water quality of large quantities of surface stored raw oil shale. Secondary objectives are to estimate the quantities of leachate water likely to be available in field locations and to combine these data with data on leachate concentrations in order to estimate potential loading of receiving waters with dissolved solids, trace elements, and organics.

Data will be obtained by subjecting columns of mined raw shale to leaching tests under a variety of flow rates, conditions of aeration, and column lengths. Raw shale and effluents will be analyzed for common ions, trace elements, and total organics. Samples of native soil will be leached under similar conditions for comparative purposes. The term of this project is from October 1978 to March 1980.

Field Leaching Study of Raw Mined Oil Shale

Colorado State University, the Area Oil Shale Office, and the Rio Blanco Oil Shale Company, as well as the U.S. Environmental Protection Agency will be involved in this cooperative research project. U.S. EPA will be responsible for coordinating activities with the Area Oil Shale Office and Rio Blanco Oil Shale Co. The principal investigator, Dr. David McWhorter, is currently attempting to establish, in the laboratory, the potential of raw oil shale stored on the surface to release undesirable chemicals to water passing through the shale. The proposed new study is to verify laboratory results under actual field conditions.

The leaching characteristics of raw oil shale will be investigated under field conditions by establishing an experiment on the C-a federal lease in cooperation

with the Rio Blanco Oil Shale Company. The specific objectives of this project are: 1) to determine the quantity and quality of leachate from raw surface stored oil shale under field conditions; 2) to compare the quality of leachate obtained under field conditions with leachate observed under laboratory conditions in an attempt to define the role of such factors as percolation rates (resident times), wetting and drying cycles, other weathering agents, and the affect of the chemistry of the influent water on the quality of leachate water; and 3) to project from these and other relevant data the potential for contamination of natural waters by leachate from surface stored raw mined oil shale.

The data from this project will identify the water quality characteristics of leachate from raw stored shale for the particular material and site conditions investigated. Hopefully, comparison of these data with currently available data from laboratory leaching tests of several different materials will allow researchers to make generalizations that can be applied elsewhere. Also, the investigators expect this project to contribute to establishing the necessity for control measures and to formulating such measures, should they prove necessary. A final report will be available in 1983.

Air Emissions from Old In Situ Oil Shale Sites

Science Applications, Inc., conducted a field testing program to determine if air emissions are being released from old in situ oil shale sites. The project entailed field sampling of soils and air at six sites of previous in situ or surface oil shale retorting activity and at one location away from any oil shale development which served as the control. Four soil samples and one air sample were collected at each of the seven sites.

Soils were tested for SO_2, total organics, hydrocarbons, pH and soil atmosphere SO_2. Air samples were tested for SO_2 and hydrocarbons. A final report will be available in 1980.

Process Oil Shale Reclamation--Davis Gulch Study

This five year project will study the moisture movement in TOSCO II processed shale. Two disposal plots will be constructed 50'x50'x10' with 10' diameter 32' deep columns for obtaining information on moisture infiltration below the zone of evapotranspiration.

3.3 Processing

The main areas of the IERL-Ci processing program are: environmental assessment, analytical methods development, control technology development, and pollution control guidance. FY 1979 research activity on oil shale processing includes eight major projects. A major pollution control guidance document has been funded for FY 1980.

Environmental Characterization of Geokinetics' In Situ Oil Shale Retorting Technology

The object of this research program was to physically, chemically, and biologically characterize air emissions and water effluents from true in situ oil shale retorting. Geokinetics, Inc., agreed to allow Monsanto Research Corporation to sample and analyze emissions and effluents from Retort No. 17, a pilot-scale unit, located on the "Kamp Kerogen" site in Uinta County, Utah, producing 30 barrels of crude oil shale per day. The potential pollution sources tested were the retort off gases before and after mist elimination, the exhaust from thermal incineration of the demister outlet gases, fugitive gas seepage through the retort surface and around well casings, retort water after oil separation, and evaporating pond water.

Three stack gas streams were analyzed for criteria pollutants (carbon monoxide, hydrocarbons, oxides of nitrogen and sulfur, and particulate matter) as well as ammonia, arsenic, hydrogen cynide, and trace elements. Carbon monoxide, total hydrocarbons, and C_1-C_6 hydrocarbon fractions were qualified in the fugitive emission samples. Conventional pollutants and water quality parameters, organic priority pollutants, and trace elements were measured in the samples of retort waters and evaporating pond water. Selected air and water pollution samples were tested for biological activity, using the Ames mutagenicity assay, the Chinese hamster ovary (CHO), clonal toxicity assay, and the rabbit alvcolar macrophage (RAM) cytotoxicity assay.

The draft final was submitted in February, 1980, by Monsanto Research Corporation. This report covers the period from November 22, 1978 to December 21, 1979; work was completed January 18, 1980.

Assessment of Oil Shale Wastewater Treatment and Control Technology

The work and services Monsanto will perform under this contract include: the definition of pollutant discharges, detailed treatability studies, and development/testing of control technology.

The approach will be to establish a specific list of water pollutants and their sources to provide a guideline for the assessment of pollutants and the design of the field pilot-scale water pollution control devices to be fabricated and tested in subsequent project phases. The pollutants identified will be those contained in oil shale retort wastewaters from surface retorts and in situ retorts whose wastewaters are treated in above ground processing equipment.

Air Pollution Investigations of Oil Shale Retorting: In Situ and Surface

Characterizing the effluent streams associated with oil shale processing is necessary from a standards and control technology standpoint. Oil shale developers at a recent meeting agreed that a commercial-size facility should be built and the environmental impact determined. The risks involved in such a venture are considerable and thus far only pilot-scale operations have been conducted. It was EPA's position that small air pollution control devices could be "slipstreamed" into some of these oil shale operations and valuable information on emissions and control technology could be obtained.

To satisfy this goal, funds for assessing the control of particulates, hydrocarbons, trace metals, and toxic chemicals were provided for both in situ and surface retorts. The initial year's work consisted of emissions evaluation, design, construction, and shakedown. Later work will include extensive field tests at in situ and surface oil shale retorts. To date evaluation of available data relative to the collective systems has been completed, and a wet scrubbing system was recommended for testing. Testing will be completed by August 1981.

H_2S/SO_2 Control Technology Study for Oil Shale Effluents

Hydroscience, Inc., in Tennessee has signed a two-year contract to determine the applicability of sulfur treatment technologies to oil shale effluents. The approach will be to review all the available data on sulfur emissions from oil shale processing facilities, evaluate the potential of all applicable sulfur emission control systems and recommend the best type of control technology. A final report recommending the best system is due in June, 1980. To date, review and evaluation tasks have been completed.

Analytical Methods Manual for Oil Shale Effluents

Many of the personnel involved with analytical measurement of oil shale effluents expressed a need to the EPA for improved reliability of chemical methods applied to oil shale analysis. The Denver Research Institute's first year's work on a contract responding to that need was an investigation of methods used by oil shale analysts. Reliable methods were distinguished from methods of questionable validity. A report entitled Oil Shale Analysis: A Review will soon be available. Methods identified in this report as needing additional development will be studied in the laboratory in the two remaining years of the contract. The Analytical Methods Manual for Oil Shale Effluents will be the end product of this research.

Overview of the Environmental Problems of Oil Shale Development

This study updates information on current and projected oil shale development plans for the Piceance and Uinta Basin areas of Colorado and Utah. Projections of shale oil production levels are listed for years 1980-1996 and provide the basis for three impact assessment areas--Potential Atmospheric Impacts, Potential Surface and Groundwater Impacts, and Socioeconomic Impacts. Process and control technologies are defined and described. Impacts are assessed for development years 1982, 1985, 1990, and 1995. The study will result in publication of a current, general oil shale reference for wide distribution.

Distribution of As, Cd, Hg, Pb, Sb and Se During In Situ Oil Shale Retorting

Preliminary investigations of oil shale retorting have indicated that mercury emissions in the off gas could be significant. The volatile properties of mercury and the other elements listed above made them candidates for additional study; therefore, this project was established to develop analytical techniques for determining the trace element composition of all effluents (air in particular) and to determine the fate of As, Cd, Hg, Pb, Sb and Se during simulated in situ oil shale retorting.

Investigators will use a laboratory size retort to study the distributions of trace elements in the various effluent streams, and measure distribution coefficients for each element. Retorting conditions will be varied to determine their effect on trace element composition. Once laboratory procedures have been established, field testing will be carried out on pilot-scale units. A laboratory scale reactor was completed in December 1979. Gas phase methods for the continuous analysis of mercury have been completed and successfully field tested.

An interagency agreement with DOE's Lawrence Berkeley Laboratory was arranged to conduct a bench-scale study, and the project was initiated in October 1978. Analytical methods are to be developed and tested for the measurement of each of these elements in the gas stream. Distribution coefficients for each output stream will be determined. The effect of retorting temperature and sweep gas rates on the coefficients will be used to predict similar coefficients for field operations. Sampling strategies suitable for use during large scale field operations will be identified.

Portable Zeeman Atomic Absorption Mercury Monitor

Mercury is a toxic element which can be emitted at harmful levels from oil shale retorts. The objective of the Lawrence Berkeley Laboratory project was to construct, test, modify and calibrate a Zeeman Atomic Absorption instrument capable of online monitoring of mercury emissions in oil shale retort product gases. The instrument has been constructed, calibrated, tested, and its operation verified in field tests. (See Figures 3 and 4.)

Pollution Control Guidance Document for Oil Shale

In the fall of 1978, the Office of Research and Development of the Environmental Protection Agency began efforts to provide reference documents and guidance to EPA offices, and federal and state agencies on environmental issues related to oil shale. These documents are intended to assure that the development of a mature oil shale industry is not delayed by uncertainties regarding environmental standards, while also assuring its development in a manner compatible with national environmental goals. The first such document became available in draft form in the summer of 1979, and has been titled: "Environmental Perspective on the Emerging Oil Shale Industry."* It is expected that this document will be printed and released during the summer of 1980. The EPA is now preparing a second document, Pollution Control Guidance Document for Oil Shale, with the first draft expected in the fall of 1980.

The Pollution Control Guidance Document will present a critical and detailed analysis of pollution control alternatives for a commercial oil shale industry. The document will contain extensive information on the design, performance and cost of a wide variety of available environmental control technology options applicable to oil shale processing. Control options will be considered as they specifically apply to oil shale through the use of six case studies as a data base. The six case studies will cover the following active oil shale development projects which are expected to reach commercial operation by 1990:

TOSCO/Colony Development in Parachute Creek

Union Oil Development in Parachute Creek

White River Project at U-a, U-b using the Paraho Process

Superior Oil Multimineral Development

Occidental Development at Tract C-b

Rio Blanco Development at Tract C-a

Emphasis also will be placed on identifying important areas of uncertainty, and on specifying the assumptions made in the analysis.

The EPA envisions this document as the second of a series leading toward the eventual establishment of regulatory standards for the oil shale industry. The document is expected to serve several purposes. First, it will establish a comprehensive, state-of-the-art understanding of pollution control alternatives for oil shale using current knowledge, supported by extensive data on design, performance and cost. Second, it will provide information on important areas of uncertainty in pollution control. Third, the document

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*Called "Pollution Control Guidance for Oil Shale Development" in the Program Status Report, Oil Shale 1979 Update.

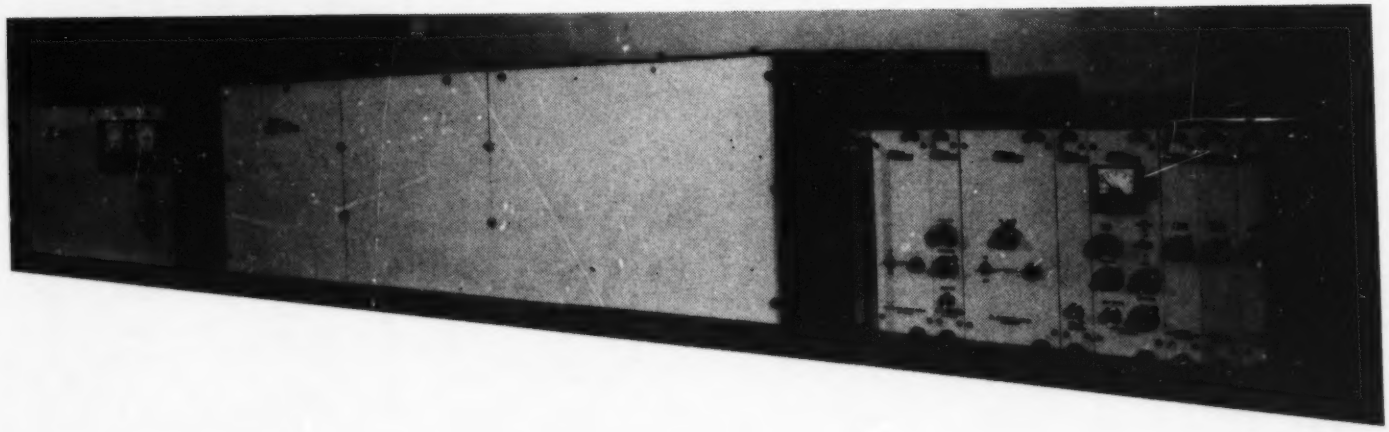

FIGURE 3. ON LINE ZEEMAN ATOMIC ABSORPTION SPECTROMETER FOR MERCURY ANALYSIS IN OIL SHALE OFF GASES
(Courtesy of the Technical Information Division, University of California, Lawrence Berkeley Laboratory)

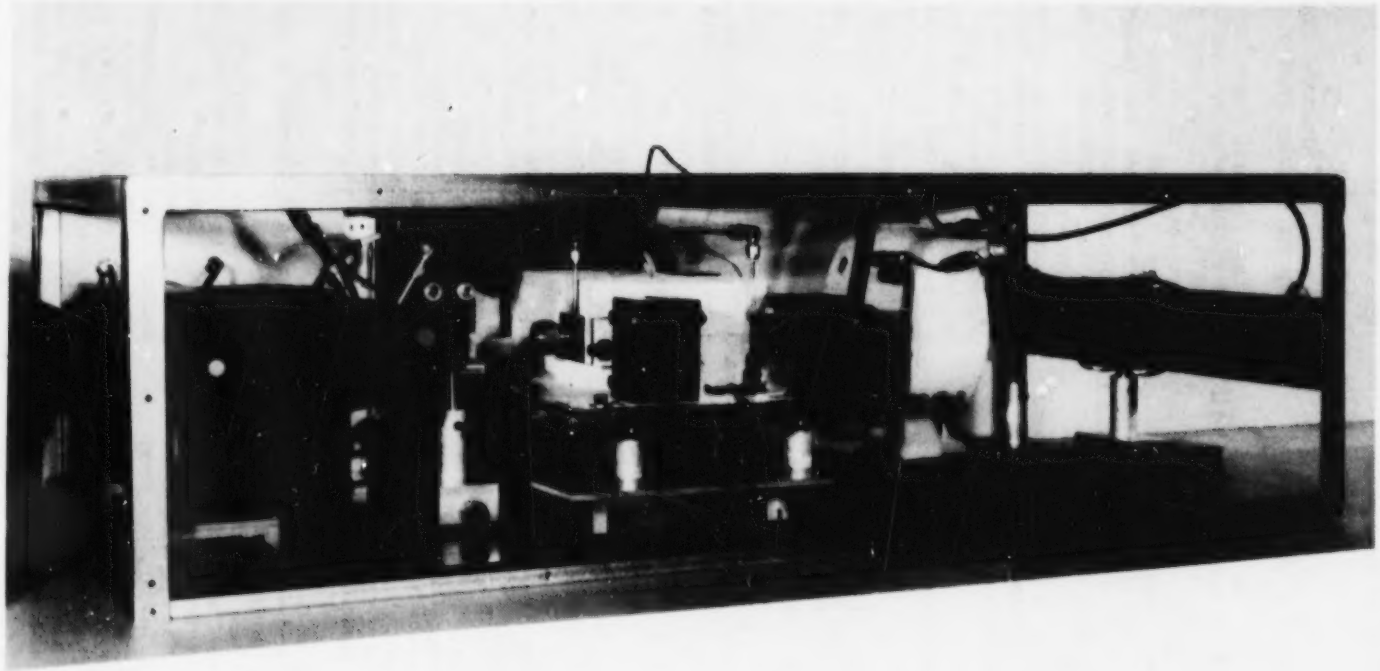

FIGURE 4. INTERIOR OF ZEEMAN SPECTROMETER. SHOWING FROM LEFT TO RIGHT: THE LIGHT SOURCE, MAGNET ASSEMBLY, SAMPLE GAS FURNACE ASSEMBLY AND DETECTOR.

(Courtesy of the Technical Information Division, University of California, Lawrence Berkeley Laboratory)

will provide a basis for communication between the EPA, industry and the public on pollution control for oil shale. Finally, the document will serve as an important and updatable reference on oil shale pollution control.

The present data base used in the development of the Pollution Control Guidance Document is incomplete, and only preliminary decisions can be made in evaluating pollution control options. The purpose is to provide a preliminary, broad base of information which specifically addresses the pollution control problems faced by the oil shale industry. Hopefully, this information will stimulate the proper concern and cooperation assuring the development of the industry in an environmentally acceptable way, and preventing delay of its development by uncertainties regarding environmental standards.

3.4 Energy-Related Processes and Effects

The energy-related processes and effects program is designed to identify and assess the environmental effects of each stage of an energy source's fuel cycle. The program is subdivided into four major areas: health effects, ecological effects, measurement and monitoring, and environmental transport processes. Current oil shale R&D activities for each of these areas are presented in the following sections.

3.4.1 Health Effects

EPA's Health Effects Research Laboratory, Research Triangle Park, North Carolina (HERL-RTP), and the Environmental Research Laboratory in Gulf Breeze, Florida (ERL-Gulf Breeze), are conducting research which deals with the effects of air and water pollutants associated with alternative forms of energy development on human health and on aquatic ecosystems.

Laboratory testing is being performed by both in vivo (whole animal) and in vitro (test tube) methods to identify and control hazardous agents. These projects are being conducted by Ball State University, Muncie, Indiana; Northrop Services, Huntsville, Alabama; and by UCLA. In addition, pass-through funds have been given to NIOSH; DOE's Lawrence Livermore Laboratory (LLL) in Livermore, California; the Los Alamos Scientific Laboratory (LASL) in Los Alamos, New Mexico; and to the Oak Ridge National Laboratory (ORNL), in Oak Ridge, Tennessee.

These projects generally are related to oil shale in that they are multi-technology oriented. The resources associated with them are not exclusively related to oil shale.

Repository for Alternate Energy Source Material for Toxicity Testing

The Chemical Repository was established at Oak Ridge National Laboratory by a USEPA/DOE Interagency Agreement to support health effects investigation of alternate fossil energy technologies. Materials suitable for research purposes are obtained, catalogued, aliquoted, and stored for distribution to health effects investigators. High priority samples are stored under controlled, documented conditions and their storage stability is monitored. Select samples are chemically or physically fractionated and characterized for high-priority studies. (See Figures 5 and 6.) Researchers have taken an active role in designing and arranging matrix studies to further existing knowledge. Results obtained from study of Repository samples are returned to the industries supplying samples.

Samples available for study include materials from coal liquefaction and upgrading, coal gasification, shale oil recovery and refining, coal combustion, and petroleum recovery and refining. A set of Comparative Research Materials from coal liquefaction, shale oil recovery, and petroleum recovery is being established in bulk quantities to support long term and extensive matrix-approach health effects research. A 340 m^3 facility for long-term and bulk sample storage under controlled and documented conditions has been constructed. Approximately 55 investigators have received more than 800 sample aliquots since establishment of the Repository. Physical or chemical fractionation and characterization has been provided for studies of materials from shale oil recovery and refining and coal combustion.

Morphological Variants in Damaged Sperm

Lawrence Livermore Laboratories (LLL), under sponsorship of the Interagency Agreement is conducting this project. Ionizing radiation as well as various mutagens, carcinogens, and teratogens are known to induce elevated levels of morphologically abnormal sperm in mice. The objectives of this study: 1) to develop further and apply the detection of morphologically abnormal mouse sperm as a rapid, simple, quantitative assay of the pathological response of the male gonad to

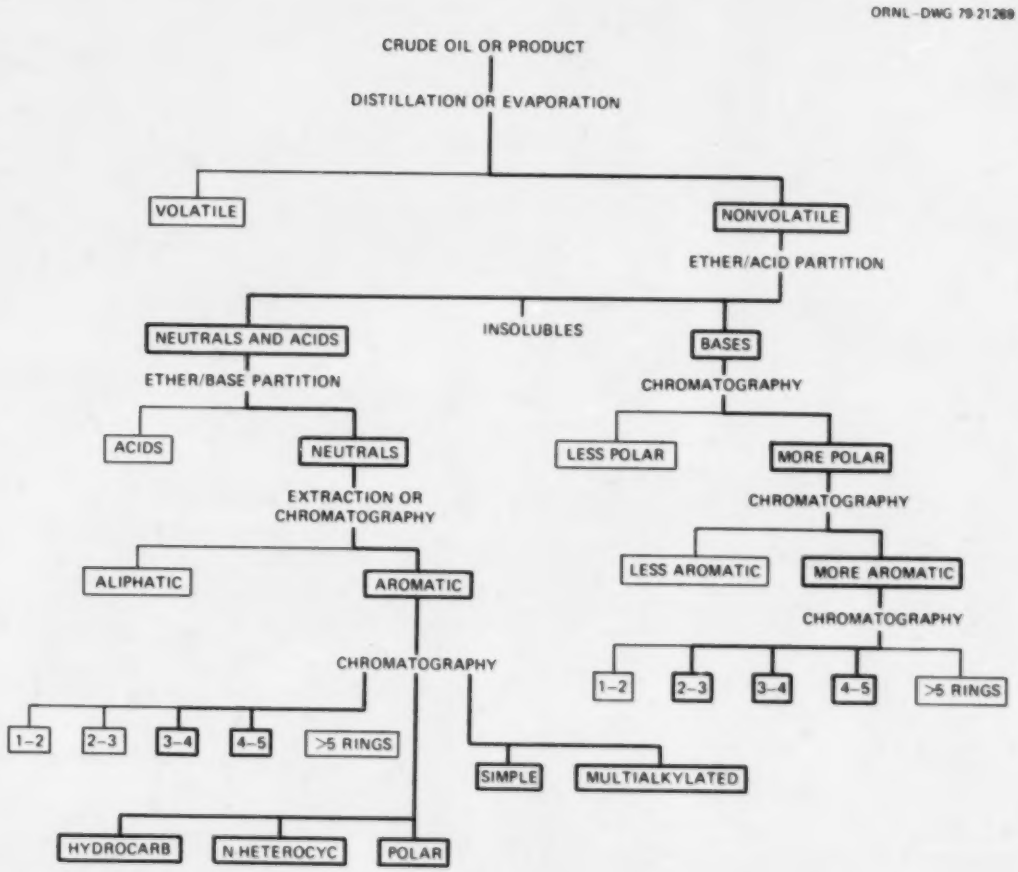

FIGURE 5. INTEGRATED CHEMICAL-BIOLOGICAL APPROACH TO SEARCH FOR DETERMINANT MUTAGENS. MUTAGENIC FRACTIONS ARE DENOTED WITH BOLD OUTLINES.

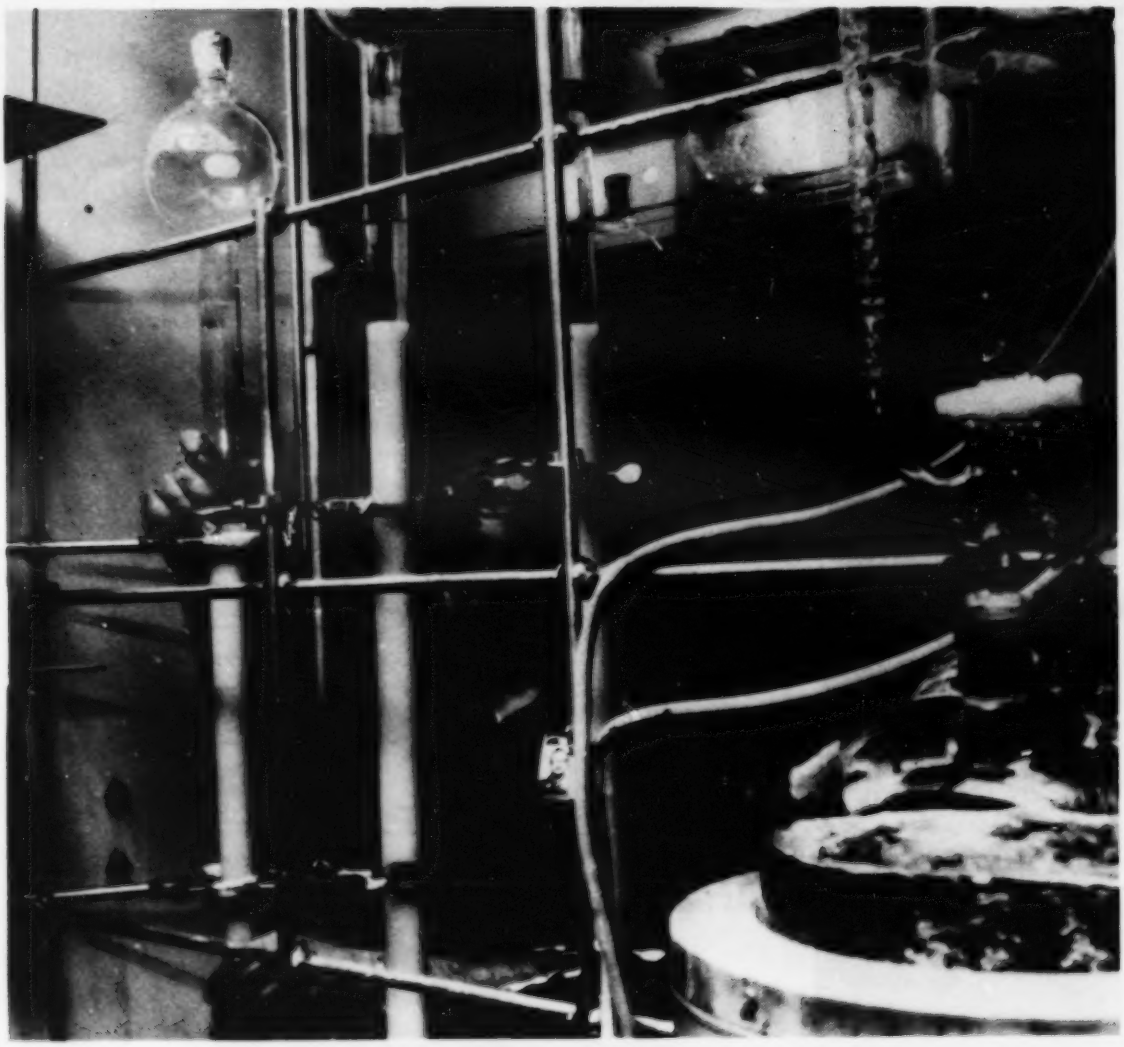

FIGURE 6. CHEMICAL REPOSITORY SPECIAL SERVICES SUPPORTING HEALTH EFFECTS RESEARCH INCLUDE SAMPLE PREPARATION. Here, a chemist sets up gel filtration columns for chemical fractionation of shale oil samples.

toxic agents; 2) to extend the studies of the mouse to the hamster; and 3) to develop the methodology for automated scoring of abnormally shaped sperm, especially after the exposure of the male to toxic agents. Of special interest are possible effects of the chemical pollutants associated with the recovery, process stream, and emission of nonnuclear sources of energy, especially coal gasification and oil shale extraction in situ.

To accomplish these objectives, groups of test mice have received subacute or chronic exposures by injection, inhalation, or dermal application. The percent of abnormally shaped epididymal sperm will be determined as a function of dosage and time after exposure. These results will be compared to those obtained by more conventional mutagens, carcinogens, and teratogens. Preliminary studies with the hamster and mouse have shown that these two species are qualitatively similar in response. Furthermore, an attempt is being made to distinguish sperm morphology in these species based on suggested differences in fluorescent dye uptake. These results may lead to automated analyses of sperm morphology. Project duration is from June 1975 to June 1980.

Detection of Early Changes in Lung Cell Cytology by Flow Systems Analysis Techniques

LASL is studying the application of modern automated cytology techniques for assessing damage to humans resulting from exposure to physical and chemical agents associated with oil shale and coal extraction, conversion, and use. The approach is to apply unique flow-system cell analysis and sorting technologies developed at LASL to determine cytological and biochemical indicators of early atypical changes in exposed lung epithelium using the Syrian hamster initially as a model test system.

Current plans are to adapt cell preparation and staining methods developed for flow systems to characterize lung cells from normal and exposed hamsters using the multiangle light-scatter systems. This includes acquiring respiratory cells by lavaging the lungs with saline, adapting cytological techniques developed on human gynecological specimens to hamster lung epithelium for obtaining single cell suspensions, using existing staining techniques for measurement of cellular biochemical properties, and initially characterizing lung cells using flow analysis instrumentation.

LASL has achieved some progress in measuring DNA content, total protein, esterase activity, cell size, nuclear and cytoplasmic diameters, and multiangle light-scatter properties of exfoliated hamster lung cell samples composed of macrophages, leukocytes, epithelial, and columnar cells. As this new technology is adapted further to analyze lung cells from hamsters and subsequent characterization studies are completed, measurement of changes in physical and biochemical cell properties as a function of exposure to toxic agents associated with synthetic fuels energy production will be performed, with the eventual examination of sputum samples from occupationally exposed humans. This project is being sponsored by DOE with EPA pass-through funds. Term of this project is from 1976 and is continuing.

Biological Screening Study of Shale Oil and H-Coal Liquefaction Operations

The feasibility of using short term assays to predict the potential biohazard of various shale oil and H-Coal test materials is being examined in a coupled chemical and biological approach. The primary focus of the research is the use of preliminary chemical characterizations and preparation for bioassay, followed by testing in short term assays in order to rapidly ascertain the biohazard.

Using crude and/or fractionated materials, simple bioassay systems are used to determine which materials or fractions thereof are biologically active, thus aiding in the assignment of priorities for further chemical separation and characterization. Additionally, secondary screening of partially defined constituents aids in identifying the appropriate mixtures, classes, or specific compounds that require testing in intact animal or plant systems. Conversely, complex materials that are known or prove to be active in higher organisms can be dissected with the short term tests and again, detailed chemical analyses can be regulated after observation of biological (genetic) activity. The overall approach may validate the use of short term genetic screening systems to predict mutagenicity and carcinogenicity for intact organisms and man. Implied in the coupled chemical-biological approach is the application and further development of bioassays involved not only in detecting hazardous materials in environmental effluents and process streams, but also in measuring and monitoring these materials via bioassays in the general environment, in the work place, and during their storage (or disposal) and transport. Furthermore, the prospect of applying short term tests to the monitoring

of exposed individuals through cytogenetic assays or microbial screening assays utilizing body fluids is under development. Preliminary information concerning the metabolic mechanisms of activation, the definition of cellular and molecular mechanisms of damage and the repair of key compounds (from the major classes of chemical pollutants) is accumulated along with the determination of potential genetic biohazard.

The H-Coal program will be carried out in two phases: Phase I will use samples that are currently available from pilot-demonstration scale operations; short term mutagenesis, cytotoxicity along with mammalian toxicity and skin carcinogenesis assay will be carried out with these materials. Phase II will use samples developed when the H-Coal plant is underway. Phase I tests (already underway) will include the H-Coal raw distillate and various stages of upgrading along with H-Coal products. These preliminary assays will parallel existing efforts with other syncrudes. The information received should aid in selection of actual process samples for evaluating the Catlettsburg, Kentucky, H-Coal pilot plant now under construction. It will also provide useful comparison of the changes which occur in the biological characteristics of specific process liquids as a function of scale-up.

The principal focus of the Paraho/ SOHIO Shale Oil project is the testing of primary effluents and products for potential effects on man. This portion of the evaluation of Paraho samples is concerned with questions of relative toxicities of process materials and refinery products.

Information gained in the preceding integrated program should provide the assessor with specific information on specific process materials. The generic approach coupled with the chemistry, health effects studies, and environmental studies should place these materials in context with respect to the data base currently available. Direct information on the potential mutagenicity, carcinogenicity, and overall toxicity of the multiple test points can be placed in perspective with other technologies. Comparative information and the published data on similar materials again should place some ordered estimate of biohazard on each unit.

All short term bacterial determinations within Phase I of H-Coal have been completed. A reduction in activity parallels the level of hydrotreatment. Distillation studies with available samples have shown that mutagenic activity parallels the heavy distillate (aromatic fractions?). Cytotoxicity work can be summarized in a similar manner -- "toxicity is reduced with hydrotreatment."

Evaluations with the Ames assay on the crude shale oils versus hydrotreated oils has reinforced results with synthetic fuels from liquefaction, i.e., a reduction of activity. Cytotoxicity work parallels this observation.

Selected fractions are being tested in comparative short-term systems. Choice of samples (and/or fractions thereof) to be extended to validative testing will depend on both the preliminary biological work and the chemistry. The validation (extension to higher organisms) will include tests for mutagenesis, e.g., mammalian cell gene mutation, whole-mammal mutation (mouse) and Drosophila; and for cytogenetic damage, e.g., sister-chromatid exchange.

Mammalian toxicity assays are also being run on a variety of distillates and oils. These assays will include acute oral LD_{50} in mice, acute skin toxicity in rats, primary skin and eye irritations, and dermal sensitization. Selected samples are also under test in subacute and chronic dermal toxicity assays including skin carcinogenesis.

Detection of Oil Shale Related Mutagens Using Human Cell Cultures.

To minimize occupational and environmental hazards possibly associated with the development of oil shale, short-term in vitro biohazard assays are being tested. The complexity and heterogeneity of oil shales, combined with the variety of processing technologies, generate products and by-products too numerous to test using whole animal assays alone. Furthermore, the time involved is too long for such analyses to be used for modifying technologies. Therefore, mutagenicity assays, employing bacterial or animal cells, are generally accepted as short term in vitro biohazard assays. However, when the amounts of potential products are as large and diverse as those accompanying full scale oil shale production, the 60-90% accuracy for predicting carcinogens usually obtained in vitro may not be acceptable and must be accompanied by mutagen-activation procedures. The use of human cells, both as activators of promutagens and as targets of mutagenic activity, could significantly increase the potential of these in vitro assays for determining carcinogenicity/ mutagenicity in humans. Techniques have been employed to culture newborn foreskin keratinocytes. These cells maintain the ability to metabolize the

carcinogen benzo[a]pyrene (B[a]P) during a number of passages in culture. Initially, these cultures will be used as a source of metabolic activation with normal human fibroblasts as targets.

Results to date using human cells as targets of mutagenic activity and rat liver S-9 or NUV radiation as activation systems have been obtained for known model carcinogens, shale oil process waters and DMSO extracts of shale oils. These results have been compared with those obtained using Salmonella, PM2, DNA and CHO cell targets. A 6TG^R (hgprt locus) mutation assay system has been adapted to early passage cultures of human embryonic skin fibroblast cells (GM10). More than 98% of the chemically induced 6TC^R mutants isolated have undetectable or greatly reduced HGPRT activity (less than 3% of the parental activity). One of the isolates has been used to perform reconstruction experiments to determine the optimal conditions for selection of these mutants.

The mutagenesis of three model procarcinogens (B[a]P, 3MC and DMN) has been studied in the newly developed human fibroblast assay incorporating liver microsomal S-9 preparations from Aroclor-induced rats. At a constant amount of S-9 protein concentration, a linear increase was seen in mutagenicity as a function of procarcinogen dose. In addition to the study of model compounds, the mutagenicity of a shale oil product water derived from surface retorting has been determined in the human mutation (6TG^R) system without rat liver microsomal activation. Preliminary results indicate substantial cytotoxicity and mutagenicity in cultures of human embryonic skin fibroblast cells (the human cells are approximately ten times more sensitive than CHO).

Several newborn epidermal keratinocyte cultures have been established. Early results show that the epidermal keratinocytes retain their characteristically high metabolic activity for a number of passages as determined by conversion of ^{3}H B[a]P to water-soluble metabolites. A squamous carcinoma cell line has been found to retain this metabolic activity at a level equal to the normal skin keratinocytes. Both types of human epithelial cells are sensitive to B[a]P, DMBA and 3MC. Currently being examined are the PAH metabolites and DNA adducts produced by the two types of human epithelial cells.

Preliminary results of studies compare responses in human cells with those utilizing other targets. "Photoactivity" in product waters has been examined from three different shale oil retort processes currently being developed: surface, vertical modified in situ and horizontal modified in situ. When the product waters are adjusted to equivalent absortivity in the NUV region the photoactivity was in the order of surface > vertical MIS > horizontal MIS. Photoactivated product water from the surface retort process was extremely more cytotoxic toward human skin fibroblasts than the product waters of either of the other two processes. Nevertheless, preliminary spectral analyses of these waters and of organic extracts of the crude oils themselves indicate differences in composition exist such that results seen in the in vitro DNA assay are not simply quantitative.

Experiments, which are in progress, have been designed to examine the photoactive components in process waters and in shale oils and determine their fate in subsequent steps of product water disposal and refining (e.g., hydrotreatment) of the crude oils. Preliminary results indicate a substantial reduction (7-fold) in photoinduced strand breaks in DNA for dimethyl sulfoxide (DMSO) extracts of hydrotreated surface retort oil compared to DMSO extracts of untreated crude oil itself (estimate based on photoactivity existing in extracts adjusted to equal A_{350} units). Furthermore, DMSO extracts of resulting sludge (a by-product of hydrotreatment of crude oils) show a similar reduction in "photoactivity" when tested for their ability to induce breaks in our in vitro DNA assay. Experiments are in progress to examine the "photoactivity" of these treated samples in regard to their potential to induce cytotoxic and mutagenic events in cultured human skin fibroblasts.

In Vivo Screening for Gene Mutation In Mouse Germ and Somatic Cells

DOE's ORNL is conducting this study with EPA pass-through funds. In screening for mutagenic agents it is important to include mammalian tests for gene mutations. In this project, identification of mutagens associated with coal and oil shale technologies that can induce gene mutations and small deficiencies will be accomplished by scoring for transmitted specific-locus mutations induced in germ cells, and somatic mutations in coat color genes.

The specific-locus method developed has been used extensively in radiation work and has already proved its usefulness in chemical mutagenesis studies. It is the only established, reliable, and definitive test for transmitted gene muta-

tions and small deficiencies currently available in mammals. To make the method economical for screening purposes, it will be used to test the mutagenicity in a whole mixture of compounds, for example, in an effluent. One mixture from a coal conversion process that has just become available after studies with nonmammalian systems is now being used in preliminary toxicity tests. An in vivo somatic-mutation method, developed in an earlier X-ray experiment, has now been explored for its usefulness in the prescreening for germinal point mutations induced by chemicals. In an array of compounds tested, parallelism with spermatogonial specific-locus mutation rates was found, indicating that the in vivo somatic-mutation tests may detect point mutations in addition to other types of genetic changes that lead to expression of the recessive gene. The method is now being used to test fractions from coal conversion processes. Term of this contract is from 1976 and is continuing.

The Carcinogenic Effects of Petroleum Hydrocarbons on Selected Marine Estuarine Organisms

The in vivo and in vitro metabolism and excretion of model hydrocarbons is being investigated in vertebrate and invertebrate marine species that serve as human food sources. The effects of temperature and exposure to other pollutants on the processes involved are also being studied. Both cytochrome P-450 dependent microsomal mixed-function oxidases (that can convert unsaturated hydrocarbons to reactive and toxic epoxides) and those enzymes that further metabolize and detoxify alkene and arene oxides are being characterized in untreated fish and fish pre-oxidized to environmental contaminants including polycyclic aromatic and polyhalogenated biphenyls.

Quantitative Mutagenesis Testing in Mammalian Culture Systems

Lawrence Livermore Laboratory will develop and apply quantitative and multiple-marker assays utilizing cultured mammalian cells to evaluate the potential mutagenic effects of agents derived from energy technologies. Additionally, LLL will use these existing and newly developed biological screening systems to identify mutagenic agents associated with coal and oil shale extraction, conversion, or use.

This program proposes the use of multiple drug-resistance markers for forward mutation in cultured Chinese hamster ovary (CHO) cells, as well as in vitro and host-mediated in vivo/ in vitro procedures in the Syrian hamster embryo (SHE) system. The markers being developed measure the frequency of forward mutation at the recessive azadenine-resistant marker, the X-linked azaguanine-resistant phenotype, and the dominant ouabain-resistant locus. Established prokaryote and lower eukaryote systems will be used for comparison and reference; the most satisfactory markers in all systems will then be combined into a standard protocol in which each of the gene loci can be measured for mutation following exposure to a particular test agent or combination.

To date, both CHO and SHE systems have been tested with the standard mutagen EMS, and experiments using specific hydrocarbons relevant to energy technology are now underway. This project is being sponsored by DOE under pass-through funds from EPA. Project duration is from June 1975 to June 1980.

Development of Cytochemical Markers for Cell Transformation and Carcinogenesis

LLL is developing rapid, sensitive, and economical systems for in vitro and cytological assays for carcinogenic effects of substances involved in extraction, conversion, and use of nonnuclear energy sources, with particular consideration of in situ coal gasification, shale oil use, coal burning power plants, and geothermal power plants. The approach is based on the development of cytochemical markers for cell transformation, and on the ability to quantify such markers by microfluorometry and by flow system analysis and sorting.

There are two phases to this work: 1) the development of appropriate test systems whose response is defined by well characterized and representative carcinogenic agents, and 2) the application of such systems to substances released by energy technologies, and including testing with whole and fractionated samples of effluents. This project is under the sponsorship of DOE with pass-through funds from EPA. Project duration is from June 1975 to June 1980.

Analysis of the Effects of Energy Related Toxic Materials to Karyotype Stability in Mammalian Cells

LASL is developing systems for the rapid detection of karyotypic changes in mammalian cells resulting from exposure to energy-related environmental pollutants,

and to screen selected subjects. Flow microfluorometry (FMF) of isolated, fluorescently stained chromosomes will be used to identify chromosome aberrations, and FMF of stained intact cells will be used to detect mitotic nondisjunction. Cadmium will be used as the clastogenic agent in the development of a test system. It has been demonstrated that chromosome analysis can be accomplished by flow systems in mammalian cells with relatively simple karyotypes. Cadmium at low concentrations is a potent clastogen. It induces primarily chromatid-type aberrations.

LASL has also demonstrated that tolerance to the damaging effects of cadmium can be induced in fibroblast cells in culture by long-term exposure of the cells to sublethal concentrations of cadmium. There are plans to repeat these experiments on human fibroblast and lymphocyte cells in vitro and to extend these studies to other toxic agents associated with alternative energy technologies. This project is being sponsored by DOE with EPA pass-through funds. Term of the contract is from 1976 and is continuing.

Effects of Products of Coal and Oil Shale Conversion on Cell Cycle Kinetics and Chromosome Structure

LASL is providing a means for detecting and monitoring damage to humans as a result of exposure to various toxic chemical and physical agents. To obtain an idea of the parameters to be monitored in humans, it is first necessary to establish the effects of agents on cells in simpler model systems.

Earlier experience with drugs which act as carcinogens and teratogens has convinced researchers that changes in population cell-cycle distribution and alterations in chromatin structure may provide useful early indicators of sublethal damage to cells exposed to hazardous agents. Examination will be made of alterations in these parameters following exposure to specific energy-related toxic substances in currently available tissue-culture systems which show promise as predictive indicators of response in humans. A technique has been developed that allows preparation of both cycling and noncycling cell populations in tissue-culture, mimicking these classes of human somatic cells. By combining autoradiography, cell number enumeration, and flow microfluorometry, it will be possible to obtain highly detailed information on the cellular kinetics response of both arrested and cycling populations to treatment with toxic agents.

Results obtained to date suggest that DNA interactive agents elicit different types of kinetics responses in treated cells, indicating a degree of specificity of interaction between various alkylating and intercalating agents and the genome. This project is sponsored by DOE with EPA pass-through funds. Term of the contract is from 1975 and is continuing.

Mutagenicity Assay of Fractionated Coal Conversion and Oil Shale In Situ Retorting Products

ORNL is monitoring environmentally important processes for genetic damage using rapid screening assays to identify mutagenic agents. They have extended an initial work on the crude product from a coal liquefaction (Syncrude/COED) to subfractionation and have identified the potential genetic hazards with the Ames system. The most active fractions appear to be the neutrals and the basic (ether soluble) components prepared by liquid extraction procedures. Parallel identification work by the analytical chemistry division has been carried out and a selected group of polycyclic compounds involved has been assayed and evaluated for mutagenicity. The crude product assays have been extended to the separator liquor components of the same process, again using the coupled analytical-biological assay approach.

Similarly, parallel studies with fractionated materials have been initiated with the Synthoil Process (liquefaction), the Synthane Process (gasification), and the shale oil in situ retorting process. Primary fractions of various steps or materials from these processes have been prepared and assayed for potential genetic damage.

The mutagenicity of crude industrial products and effluents was arrayed with the Salmonella/microsomal activation system. Test materials (crude products from coal conversion processes and natural crude oils) were initially fractionated into primary classes by liquid-liquid extraction and then further fractionated by column chromatography. Prescreening was accomplished over a wide concentration range with the Ames tester strains. Active fractions (mainly the neutral fractions containing polycyclic aromatic hydrocarbons and certain basic fractions) can be identified, and dose-response relationships can be established. Standard values are expressed as revertants per milligram of the test material assayed with frameshift strain TA98 including metabolic activation

with rat liver preparations. Total mutagenic activity of synthetic fuel samples was consistently higher than that of natural crude controls. Activities of subfractions are roughly additive and presumably reflect the mutagenic potential of the whole test material. These results are being extended to other genetic assays. Chemical identification is carried out along with the bioassays.

The application of short-term mutagen tests was evaluated using bacterial, fungal, mammalian cells and Drosophila on synfuel A fraction. The results of the use of these systems simply show that biological testing and genetic assays, in this case, can be carried out with the developed tester systems, but only when coupled with the appropriate analytical separation scheme.

The Quantitative Evaluation of Hazardous Chemicals Using a Closed Aquatic Test System

Brookhaven National Laboratory is developing a new comparative test system, using clones of fish, P. formonsa, capable of detecting the carcinogenicity of chemicals by treatment of cells in vitro or by treatment of whole animals.

The approach is to treat cells in vitro with presumptive carcinogens by injecting cells into fish and scoring recipient fish for tumors one or two years later, or introducing presumptive carcinogens directly into the water tank to assess their effects on the whole animal. This is a continuing program that began in 1976.

The Interaction of Chemical Agents Present in Oil Shale with Biological Systems

The aim of this project is identifying reactive free radical intermediates formed during the co-oxygenation of benzo(a) pyrene (BaP) and other polycylic aromatic hydrocarbons (PAH) using two approaches: the direct observation of free radical intermediates and the trapping of such reactive compounds using spin traps. Research into the bioeffects of shale oil and the effluents associated with conversion to synfuels is performed on the polycyclic aromatic hydrocarbons and the heavy metal ions.

Development of Permanent Epithelial Cell Lines

DOE's ORNL is conducting this study with EPA pass-through funds. Objectives are: 1) to develop the means by which chemicals associated with nonnuclear energy generation, especially agents arising from coal and oil shale extraction, can be screened for potential carcinogenic activity. Reliability, speed, and cost relative to current animal exposure techniques, are emphasized; 2) to utilize appropriate cultured cells developed under the first objective to study hydrocarbon metabolism into carcinogenically active forms, and determine the mechanism of chemical carcinogenesis.

A research group with two discrete but closely related approaches to these problems is being developed. The approaches are: 1) cell biology--the major focus here will be the development of permanent cell lines of epithelial origin (human, when possible and appropriate) which possess the enzymatic equipment for carcinogen activation and which are transformable with high frequency; and 2) biochemistry--the principal focus will be study of the metabolism of polycyclic hydrocarbons in various cell lines developed in the first approach to establish with certainty the "ultimate" carcinogenic metabolite, using primarily high pressure liquid chromatography techniques. This contract was initiated in 1976 and is continuing.

Development of an In Vitro Assay for Cocarcinogens of Coal/Oil Shale Derivatives

The UCLA School of Medicine is developing an in vitro assay capable of detecting the cocarcinogenic potential (with X-rays) of materials produced during coal and oil shale processing. Investigators intended to use mouse tissue cultured cells and an already established transformation assay, but initial experiments indicated that rodent cells may possess lesions induced by alkylating agents different from human cells and that their use as screening materials might be misleading. This effect was shown by demonstrating that a variety of DNA damaging agents had significantly different effects on various cell lines when measured by a variety of techniques.

It was hypothesized that a ventral difference between the lines (rodent versus human) may be the "activation of on-cogenesis" related to the strand breakage induced, because rodent lines carry transforming virus materials (complete or incomplete), which are lacking in most human target cells. These differences are being evaluated through cell hybridization analysis using hybrids made by sendai-virus fusion of cells lacking either:

1) different DNA repair enzymes, or 2) (potential) RNA viruses. This project is sponsored by DOE with EPA pass-through funds. The contract began in 1979 and is continuing.

Influence of Diet on the Gastrointestinal Absorption of Energy Related Metallic Pollutants

In a study of the absorptive interactions of cadmium and zinc using everted gut sacs, no effect of zinc on cadmium accumulation in the intestinal tissues was apparent, but there appears to be a subtle increase in the serosal fluid accumulation of cadmium during 30 minutes of incubation. Zinc uptake and transport by intestinal tissue was stimulated in the presence of cadmium. In a long-term chronic exposure of rats to cadmium, the body retention of zinc was increased for those animals drinking water with 1, 10 or 25 ppm cadmium. Studies have been initiated to determine the kinetics of the intestinal absorption and transport of lead using everted gut sacs.

3.4.2 Ecological Effects

The Environmental Research Laboratory in Duluth (ERL-Duluth) is providing predictions on potential aquatic toxicants resulting from coal and oil shale extraction and conversion. Current work involves chemical characterization and bioassays of retort process waters and chemical and analytical studies of water in the Piceance Creek basin. Term of the present projects is 1975 - 1980.

This five year project will fully assess and evaluate the adequacy of waste treatment methods, so that the aquatic environment will be protected. Research involves: chemical identification and measurement of waste products, acute and chronic bioassay studies with invertebrates and fish, determination of the physical and chemical fate of organic contaminants, and determination of the uptake and bioaccumulation of trace pollutants. Results of the research will be published, and used to evaluate waste treatment methods for coal gasification and oil shale for technologies.

Concentration of Well Waters from an Oil Shale Retorting Site for Biological Testing

The overall purpose of this project is to determine the potential harmful biological effects of organic substances introduced into ground waters during in situ oil shale retorting.

Samples of water from tract C-a will be collected and concentrated by reverse osmosis and then sterilized by membrane filtration. The samples will be biologically tested at the Health Effects Research Laboratory, Cincinnati. Samples taken before and after retorting will be compared in another task under separate contract. The following actvities and completion dates have been projected:

Sample collection, pre-burn	October 1979
Sample collection post-burn	June 1980
Draft final report	July 1980
Final report	August 1980

HERL-Ci will test the samples from November 1979 through March 1980 and report results separately. Chemical analytical results used to characterize the samples will be discussed and related to the biological tests in the final report.

Biological Guidelines for Integrated Environmental Monitoring for Mined Lands

There are no effective, standardized user-oriented guidelines for designing, conducting and evaluating ecological baseline and environmental monitoring programs for energy and other resource development. Both reclamation and use of control technology will require a well-designed environmental baseline and monitoring program. Although environmental protection guidelines for coal, oil shale, and other energy programs on federal lands are published in the Federal Register, enforceable guidelines flexible enough for use in different geographic areas and for operations with quite different potentials for environmental damage are needed. The Fish and Wildlife Service has developed a work, under EPA funding, specifically defining requirements for ecological baselines.

Phase I of the study will include guidelines for design, implementation, verification, and evaluation of environmental baselines, monitoring, and general ecological impact assessment. The focus will be national, and site-specific monitoring needs will be identified. Phase II will provide instructions for assessing and using monitoring techniques.

The energy industries (coal, oil shale, geothermal, etc.), the CEQ, EPA, OSM, DOE, the land management agencies, various state and county governments, universities, consulting firms, and private landowners will be able to use the results of the study in conjunction with current monitoring requirements.

This study will be done in-house (Fish and Wildlife Service) through contracts and through direct and indirect support of state and wildlife groups, land management agencies, private industry, and universities. The proposed effort will be guided by the Western and Eastern Land Use Teams. The study will require continued involvement of the groups and agencies listed above.

User-oriented manuals which will guide the various groups in planning and implementing environmental baseline and monitoring programs will be produced. The manuals will be designed for immediate use by EPA, OSM, other regulatory and management agencies, environmental consulting firms, and industry.

Developmental Markers and Reproductive Damage

Previous work has demonstrated that macromolecular yolk precursors as well as heterologous materials present in the maternal bloodstream are incorporated by the growing egg, stored in compartmentalized membrane-bound inclusions and used during embryogenesis. Thus, it appears that environmental materials present at subthreshold levels of toxicity in the adult female will be acquired, concentrated and stored by growing eggs, and made available to the embryo when the yolk compartment is used. Better laboratory methods are also needed to assess rapidly and reliably the effects of pollutants on the reproductive potential of aquatic vertebrates.

Essentially this project involves studying egg formation, fertilization and early embryonic development in fish and amphibians, both of which provide copious gametes for experimental work. The research, therefore, relates to regulatory processes in two ways: 1) it provides insight into how egg formation and early embryogenesis may be greatly disturbed in all vertebrates, including mammals, by environmental substances introduced into the growing egg via the maternal bloodstream, and 2) more immediately, it allows an assessment of reproductive dysfunction in aquatic vertebrates brought about by altered water quality.

Studies are being conducted primarily on two animals: the obligately aquatic amphibian, Xenophus laevis (easily maintained at inland laboratories), and the estuarine fish, Fundulus heteroclitus (abundantly available at essentially all marine laboratories along the North Atlantic coast). Developmental processes examined include four general areas: 1) oocyte growth; 2) maturation of full grown oocytes into eggs; 3) fertilization; and 4) embryogenesis. Recently it has been possible to grow X. laevis oocytes in vitro. It has been found that trivalent arsenicals, particularly phenylarsinoxide, are by far the most potent inhibitors of oocyte growth. The sequestration, translocation, turnover and/or storage of external materials by the growing oocyte is being studied in order to understand how materials externally derived during oogenesis are delivered to the growing embryo. Researchers have found that zinc at very low concentrations will initiate maturation of full grown oocytes and that cadmium competes with zinc initiation. Basic studies on fertilization are being pursued since present background information for X. laevis and F. heteroclitus is inadequate. Studies of the teratogenic effects of hazardous substances using X. laevis embryos (which can be readily obtained by the hundreds at any time of the year) are also underway. The emphasis is on structurally related chemicals present in coal conversion process waters, thus allowing statistical predictions. An integrated approach will also be initiated: the teratogenic effect of external materials will be examined by introducing these substances into the growing oocyte either via the maternal bloodstream or in culture and comparing effects on subsequent embryos obtained from these oocytes with effects obtained when the same materials are added directly to the water containing growing embryos.

This research will provide qualitative and quantitative information on the effects of pollutants on reproductive dysfunction in general (and on aquatic vertebrates in particular) and aid in identifying the causes of lowered fecundity which apply during the formation of gametes, their fertilization, and subsequent embryogenesis. This is the only project in the U.S.A. which focuses on the growth of eggs in aquatic vertebrates and/or the consequences of its perturbation and which can relate observed effects with embryological dysfunction.

Important intrinsic information on fecundity and reproductive biology will be obtained since amphibians and fish appear to be excellent organisms to use for studying and understanding the mechanisms controlling oogenesis, clutch size, fertilization and embryogenesis.

Develop Markers Reproductive-Teratological Damage

The object of the research is to identify toxic substances, primarily neurotoxins, in fossil fuel pollutants, and to determine their teratological effect. Because they tend to be water soluble, the ether soluble weak acids and bases from fossil fuels are being tested. An acute lethal toxicity assay using small goldfish in 100 ml water and taking two to four hours has been reduced to a micro assay using guppy fry and 5 ml water. This second assay shows chronic effects three to seven days following the assay. A preparative gas chromatograph has been built, which is capable of separating pure molecular species in amounts large enough to micro assay, test for enzyme inhibition and identify by GC/MS. Usually the acute lethal studies have an exposure time of fifteen hours and use biological endpoints such as changes in behavior, color, death of the animal or inhibition of nerve transmission or enzyme action. Any toxic (or potentially toxic) agent which is water soluble or can be made water soluble can be tested. The goldfish and guppy fry and acetylcholinesterase enzymes have proved useful for studying the toxic substituted pyridines in fossil fuels. Similarly, isolated fish scales and tails have proved useful in studying the anti-adrenergic phenols in the weak acid fraction of fossil fuels.

Acetylcholinesterase can be isolated from human red blood cells and readily tested. The substituted pyridines are toxic to three species of fish and inhibit eel acetylcholinesterase; therefore, they will probably inhibit the human enzyme and perhaps cause chronic damage to embryos, fetuses, and children.

Develop Guildelines and Criteria for Use of Non-Mine Wastes as Soil Amendments on Oil Shale

Determining how processed oil shale should be amended for effectively revegetating spoil materials is the overall purpose of this project.

Both greenhouse and field studies were conducted using TOSCO II processed shale with certain amendments as growing media for plants. Also several cooperative studies were developed with universities.

In the greenhouse, sewage sludge had significantly greater beneficial effects on seed germination and plant growth than wood fiber, straw, sugar beet pulp, or cow manure. Sewage sludge apparently ties up the sodium salts in spent shale. Revegetation studies on processed oil shale are being conducted at two main field locations where disposal of the material is likely to take place in the future: Davis Gulch, (Elev. 8100 ft., precip. 18 in.) at the head of Parachute Creek on the Roan Plateau in western Colorado, and Sand Wash, (Elev. 5100 ft., precip. 7 in.) in the salt desert, shrub type, southwest of Vernal, Utah. At both sites a covering of at least one foot of topsoil over processed shale increased the number of adapted plant species and greatly reduced the need for fertilizers. Although not as good as topsoil, a covering of 2 to 3 inches of rock talus over processed shale was superior to a covering of barley straw. At Sand Wash, drip irrigation during the first growing season enhanced plant survival on processed shale; but where the processed shale was covered with at least one foot of soil, survival was about equal on irrigated and non-irrigated plots. Use of container-grown plants can insure successful revegetation of arid sites where direct seeding has failed.

3.4.3 Measurement and Monitoring

Projects in this category include air, surface and groundwater monitoring and methodology development, instrumentation development and identification of wastes and effluents. Studies are being conducted by EPA's Environmental Monitoring and Support Laboratory in Las Vegas (EMSL-LV) the Region VIII office in Denver, and the Environmental Research Laboratory in Athens (ERL-Athens) cooperating with USGS, DOE and NBS.

Oil Shale Site Meteorological Data Analysis

CDM Limnetics, Wheat Ridge, Colorado, purchased upper air meteorological data from the National Climatic Center in Asheville, North Carolina, for the National Weather Station at Grand Junction, Colorado. The temperature, wind speed, and wind direction data collected at Grand Junction, Colorado, has been compared with similar data obtained near the Colorado federal oil shale lease tracts. The representativeness of obtaining upper air data for 15 days in the central portion of each quarter has been determined; a report providing this low level radiosonde monitoring data comparison has been released. This completed project was sponsored by EPA Region VIII, Denver, Colorado.

Air Quality and Surface Wind Monitoring in Colorado

The Colorado Department of Health is under contract to EPA Region VIII to install and operate air monitoring sites in selected areas of western Colorado to collect baseline data prior to major expansion of energy activities. Particulate samples from the energy area are analyzed for nitrate and sulfate content. EPA Region VIII is administering this project with OEET funds. Term of the contract is from 1975 to 1980. Data are available upon request from EPA Region VIII office.

Upper Air Meteorological Data Collection

Aeromet, Inc., Norman, Oklahoma, has collected upper air data at tract U-a/U-b from June 1, 1976 through October 30, 1977, and at tract C-b from June 1, 1976 through November 30, 1978. Temperature, wind speed, and direction versus altitude were measured via pilot balloons and temperature sondes. Single vs. double theodolite evaluations were made. Temperature and wind data were used to generate stability-wind rise data on a seasonal, annual, and monthly basis. These data also provided mixing height data.

Visibility Monitoring in Piceance Basin

Instrumentation has been provided by EPA Region VIII to lessees of Tract C-b for measurement of visibility. A comprehensive basin-wide program will probably begin in 1980. Visibility data are also being gathered at Dinosaur National Park.

Monitoring the Impact of Oil Shale Extraction on Groundwater Quality

The technical objectives of this project are to develop guidelines for design and implementation of groundwater quality monitoring programs for oil shale development considering both surface and in situ retorts in Utah and Colorado. These objectives will be accomplished by evaluating the potential impact of oil shale operations on groundwater quality, identifying and ranking potential pollution sources, assessing alternative monitoring approaches, and recommending cost-effective monitoring methods. Using general monitoring design methods developed by Tempo for EPA, currently the monitoring needs are being evaluated for oil shale developments as proposed for tracts U-a, U-b, C-a and C-b. With 1977 as the initiation of this work the proposed milestones and accomplishments are as follows:

12 months - Complete inventory of potential pollution sources for Utah-type (surface retorting) operation. Develop priority ranking of sources for monitoring. Complete compendium of oil shale mining and retorting techniques.

24 months - Complete preliminary monitoring design report for Utah-type operation.

36 months - Complete preliminary monitoring design report for Colorado-type (MIS) operation.

36-48 months - Conduct field testing and other data collection and analysis efforts needed to finalize monitoring recommendations.

54 months - Complete monitoring design guidelines for MIS operations.

Energy Related Water Monitoring Data Integration

This project will study the development of the most appropriate monitoring strategy for measuring and evaluating air and water pollutants resulting from commercial scale operations of advanced energy conversion systems. Monitoring recommendations will be provided for all phases in the development of an energy project including site selection, construction, operation, close down, and follow-up monitoring. The technologies of interest are: a) fluidized bed combustion; b) low-medium Btu coal gasification; c) in situ coal gasification and oil shale retorting; d) surface oil shale retorting, and e) direct and indirect coal liquefaction.

Development of monitoring recommendations includes identification of: pollutants likely to be discharged or to escape into the environment; optimal sampling procedures or criteria for determining source; most appropriate (in terms of sensitivity, accuracy and cost) laboratory analysis methods; data handling and reporting methods; and adequate quality assurance on all portions of the monitoring program. The ultimate recommendations will contain advice on how to deal with site specific parameters, such as complex terrain and geology. To date, the first two tasks are completed and the third task is funded.

Investigators will prepare a report containing recommendations on optimal monitoring systems for each of five new energy technologies.

Water Quality and Geochemistry of Shallow Aquifers of Piceance Creek, Colorado

The objective of this USGS program is to define the variation of water chemistry in the aquifers of the Piceance basin and its relationship to the soluble minerals of the Green River Formation. A digital model of the chemical reactions will be developed and coupled with the existing digital model of the aquifer hydraulics, and used to predict the effects of oil shale mine dewatering on water chemistry.

Water quality samples will be collected and analyzed from the wells drilled in the basin. Samples will also be collected from springs. A digital model of the water chemistry will be developed and coupled with the existing groundwater hydraulics model. The chemical data will be used to calibrate the model. Mine dewatering operations can then be simulated to predict changes in the water chemistry of the mine discharge.

The project began in July 1974. The initial interpretive phase of the project was completed September 1978. Monitoring of groundwater quality has been in progress since 1974 and will continue throughout the period of oil shale development on the prototype lease tracts. In 1976, a two-layer two dimensional solute transport model of the groundwater basin was constructed but could not be properly calibrated. The invalid assumption was that the basin was primarily a two aquifer system with water quality differences between each aquifer but not within each aquifer. It now appears that significant concentration changes may occur with depth within the aquifers and that high concentration water in some wells and springs is a composite mixture of water of greatly different quality rather than a representative sample of water quality in the aquifer as a whole. In order to consider the effects of the concentration variation with depth in the aquifers, a three-dimensional solute transport model of the basin was constructed.

Continued work in 1977 with the finite element solute transport model has shown that the program could successfully solve the flow equation representing the Piceance basin but could not solve the corresponding solute transport equations. As a result, this finite difference solute transport model was constructed and successfully calibrated in 1978, using equilibrium groundwater flow and dissolved solids concentration data.

The model has been used to simulate the effects of mine dewatering and resaturation on the groundwater quality in the basin. Simulation results indicate that enhanced vertical movement of groundwater near pumping mines in Tracts C-a and C-b will produce a zone of better quality groundwater in the deeper aquifers adjacent to each mine. The effects of spent oil shale leachate in an abandoned and resaturated mine in both tracts were also simulated. Results indicate that a large zone of degraded groundwater quality will occur downgradient of Tract C-a, while only a small zone occurs near Tract C-b. The proximity of Piceance Creek to the C-b mine causes groundwater of degraded quality to move into the stream without affecting large areas of the surrounding aquifer. A report, "Hydrochemistry and Simulated Solute Transport in Piceance Basin, Northwestern Colorado," documenting the results of this investigation has been prepared for open file release and publication as a U.S. Geological Survey professional paper.

Water Quality on White River, Parachute Creek and Logan Wash in Oil Shale Areas of Western Colorado

The project objective is to inventory the water resources and describe the hydrologic system of Parachute and Roan Creeks.

Basic water data will be collected on streamflow, sediment yields, water quality, spring discharge, and groundwater potentiometric levels. The data will be used to document the existing hydrologic conditions in Parachute Creek and Roan Creek. The data will provide a description of the relationship between surface water and groundwater quantity and quality in the study area.

The project began in July 1974 and is planned to continue through September 1980. Four continuous record surface water stations and one miscellaneous station were operated in the study area at the start of 1976. Two of these stations are equipped with automatic suspended sediment samplers and two-parameter water quality monitors. Water quality samples are collected monthly at three sites, and sediment samples are collected monthly at one site. In addition, twelve surface water stations are operated by industry. Records from these stations have been made available to the U.S. Geological Survey. Later in 1976, Occidental Oil Shale, Inc., gave permission for the use of three alluvial wells in major drainages around its in situ operation. Water levels

and water quality samples are being obtained from these wells. A deep core hole near Mount Callahan was also provided by Occidental, permitting water levels and water quality samples to be obtained in the upper and lower aquifers of the Green River formation.

By 1977, a new project in the Parachute Creek basin was funded by the U.S. Navy; the objective is to inventory the water resources and describe the hydrologic system of the U.S. Naval Oil Shale Reserve No. 1. Five surface water gauges, two automatic sediment samplers, three precipitation gauges, and one climate station have been installed on the Reserve. Data from this project will be used to supplement the existing program for Parachute and Roan Creeks.

Monitoring of surface water and groundwater quality continued in 1979. Eight surface water gauging stations, four automatic sampling sediment stations, and five two-parameter monitoring stations were maintained by USGS. Ten surface water stations were maintained by private oil companies. Ten deep core holes were drilled and hydrologic information collected on the Naval Oil Shale Reserve. Four private oil company core holes were reworked for hydrologic monitoring. Two production wells and ten observation holes were installed for alluvial aquifer testing in the Roan Creek basin. Water quality samples of miscellaneous sites were collected for 35 springs and surface water sites near existing oil shale operations. A final report on the investigation is planned for 1980 as a professional paper.

Surface Water Quality Monitoring Techniques Assessment

In 1975 EMSL-LV initiated a program designed to test and evaluate water quality monitoring approaches and procedures for application in surface waters of the semi-arid oil shale development area. A one year field effort was completed in the fall of 1976 in the downstream reaches of the White River in eastern Utah. This effort consisted of testing a number of water quality monitoring procedures including conventional grab sampling methods, portable in situ automated water sensors and samplers, and various biological sampling approaches and methods. Biological testing was continued in the middle and upper reaches of the White River throughout 1979. Sample analyses, data processing and report preparation are continuing into FY 80.

To date, three EPA ORD project reports have been published, and several technical papers presented at various EPA and non-EPA sponsored conferences. Four additional EPA ORD technical reports are currently in preparation and it is anticipated that final project reports will be published by June 1981.

The intensive macrobenthos sampling effort has resulted in the collection of more than 1,200 samples over a five year period, approximately 75 percent of which have been processed. This represents the most comprehensive macrobenthos data base in existence for surface waters of the oil shale development area. Data represented by up to 40 replicates per site/per sampling date, are available for the entire river course from the upstream cold water reaches near Buford to Asphalt Wash downstream from the U-a/U-b tracts. One of the most significant results of this project was the development and validation of a highly efficient standardized technique for sampling macroinvertebrate communities in stream reaches characterized by heavy sediment loads and highly variable water levels. Such reaches are typically difficult to sample due to the unstable nature of the substrate and the low densities of benthic animals. This technique, the Standardized Travel Kick Method (STKM), offers a highly versatile and cost-effective approach for sampling macrobenthic communities exhibiting highly variable populations.

Information relative to chemical/physical monitoring procedures indicated that a time-stratified sampling regime that provides for maximum sampling intensity during periods of greatest variability in water quality would improve sampling cost efficiency. Automated in situ water quality sensors utilized in this program proved inadequate for unattended operation in remote areas. Fouling of sensors and associated data drift presented insurmountable problems in the highly turbid downstream reaches of the White River. D.C. powered automated water samplers, on the other hand, performed satisfactorily during ice-free periods.

Biological aspects of this project were accomplished in part by UNLV biologists under EPA Contract No. 68-03-2619.

Identification of Components of Energy Related Waste Effluents

Two contractors have worked to identify components of energy-related wastes and effluents. The first contract, performed by Research Triangle Institute,

Research Triangle Park, North Carolina, has been completed. Their work was reported in EPA Research Report No. EPA-600/7-78-004, January 1978. The second contract was performed by Gulf South Research Institute, New Orleans, Louisiana, and was completed in December 1979.

Contract work was divided into two phases. Phase A consisted of a state-of-the-art summary to determine which energy-related solid wastes and aqueous effluents had already been analyzed so that pollutants could be identified and measured. Information concerning past and current relevant projects was summarized by both contractors. These reports indicated projects on analysis of samples from coal, mines, oil refineries, oil shale processors, coal fired power plants, coal liquefaction and coal gasification. The summary prepared by Research Triangle Institute was included in the EPA report mentioned above. The report was prepared by Gulf South Research Institute and is available as EPA Research Report No. 600/7-79-255.

Phase B of both contracts consisted of selecting sampling sites, and collecting and analyzing samples. Analysis of samples for all elements except mercury was performed by spark source mass spectrometry. Mercury determinations were carried out using the cold vapor atomic absorption technique. Organic compounds in the samples were identified by gas chromatography-mass spectrometry. Volatile organic compounds were determined using purge-and-trap techniques. Semi-volatile organic compounds were extracted with methylene chloride, once at a high sample pH and once at a low sample pH. Organic compounds identified were quantified using molar response ratios. Six oil shale process effluent samples were collected at the Anvil Points site, Rifle, Colorado, and are being analyzed at Gulf South Research Institute.

This work is being sponsored by EPA's Environmental Research Laboratory at Athens, Georgia.

Characterization of Dirty Aqueous Effluents from Energy Related Wastes & Effluents

This project, initiated late in FY 1978, is also being conducted at Iowa State University. The focus of this study is on developing procedures for the characterization and measurement of potentially hazardous constituents in dirty aqueous effluents.

Samples of "typical" effluents have been obtained from pilot and demonstration scale facilities now in operation. Attempts have been made to modify existing techniques and to develop new techniques for isolating organic contaminants from these effluents. Work has begun on procedures for separating sample components into fractions containing species with similar chemical properties. Procedures for the routine determination of priority contaminants are being refined, and capabilities for performing microassays have been expanded.

Isolation and separation protocols are being finalized. Routine monitoring procedures have been applied to samples taken from operating facilities. Bioassay procedures are being used to apply separation and characterization efforts to those sample components posing the greatest potential threat to the environment.

Developed procedures are being tested on real samples. Attempts are being made to identify or characterize all major components and all components which might have an adverse environmental effect.

Study of Raw Materials, Products and Residues of Coal Conversion and Oil Shale Processes for Possible SRM's: Oil Shale

The purpose of this project is to evaluate the feasibility of certifying a number of the chemical constituents of an oil shale as Standard Reference Material (SRM).

Several years ago, NBS conducted a workshop on the needs for Standard Reference Materials for oil shale processing. Subsequently, NBS conducted preliminary analyses on inorganics and organics present in oil shale.

Analyses of oil shale by neutron activation for elements having intermediate and long-lived neutron irradiation products allowed detection and concentration estimations for approximately thirty elements, ranging from 1.8% (Fe) to 0.30 (Ta) μg/g. The estimated uncertainties in the concentration values ranged from 5 to 10 percent.

High resolution gas chromatography was conducted using glass capillary columns. Extracts of oil shale analyzed with or without ^{60}Co-irradiation sterilization of the oil shale gave identical chromatograms. Evaluation of organic extraction efficiency is needed to quantify organics present in the oil shale. Related

work on organic extraction efficiencies is currently underway for quantification of organics on an urban air particulate certified for trace inorganics (SRM 1648).

A Summary Report on Oil Shale Activities at NBS has been prepared. This report recommends the development of measurements, methods, and Standard Reference Materials for oil shale processing.

Western Energy-Related Regional Air Quality Monitoring

The Western Energy-Related Regional Air Quality Monitoring Program which started in FY 75 has evolved into the Visibility Investigative Experiment in the West (VIEW). The study area for the former program consisted of eight western states (Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming) where proposed energy developments are intensive. The program consisted of a number of individual projects including a 28-station particulate monitoring network in the Four Corners area, a sulfate/nitrate monitoring network, an instrumented aircraft flown primarily over Arizona and Utah, and a visibility monitoring station. Reports and other publications describing the results of these projects are (or will shortly become) available. One task of special interest was the incorporation of air quality data collected at the three Federal oil shale leases into EPA's national air quality data base (SAROAD).

The new program is a development of the visibility and particulate characterization projects of the former program. Of primary interest to the VIEW program is the impact of energy-related air polluting sources on visibility. The program includes a visibility monitoring network of about twenty locations and a fine particulate monitoring network at over forty locations. The study area is generally the same as for the previous program. Several of the visibility monitoring and fine particulate characterization network sites are in the oil shale resource area. The objectives of the program are to establish present visibility levels and trends, to develop and test monitoring techniques, to determine the relative contributions of various sources to visibility and to establish the relationship between quantitative visibility measures and human perception of degraded visibility. The program is a joint effort of the Environmental Protection Agency, the National Park Service and the Bureau of Land Management. Information from this research is being used to formulate a visibility protection strategy for designated federal Class I areas as required by Congress in the Clean Air Act of 1977.

Air and Water Monitoring Guidelines for Advanced Coal Conversion and Combustion Plants

The objective of this project is to develop ambient multimedia monitoring guidelines for commercial scale coal and oil shale conversion facilities.

Because of significant process differences between the various combustion and conversion technologies, each requires an individually designed ambient monitoring strategy to evaluate effects on air, land and water resources.

Five separate areas are considered: four related to coal conversion or combustion and one to oil shale. The latter is to concentrate on in situ and/or modified in situ processes. Development of the monitoring guidelines will be based on existing environmental and pollutant data from test units, pilot facilities, and foreign commercial operations. Engineering projections will be used when physical data is nonexistent. For each technology a guidance document will be produced containing an identification and a ranking for probable pollutants, recommendations for and descriptions of sampling procedures and design, sample analysis methods, data interpretation and evaluation procedures, data handling and processing methods and basic reporting recommendations, and a recommended basic outline of a quality assurance program covering all aspects of sampling, sample handling, laboratory analysis and data management.

The initial product from the contract, a draft report on monitoring guidelines for fluidized bed coal combustion, was submitted to EPA in October, 1979 and is now in technical review. The guideline document for in situ or modified in situ oil shale is projected for Spring 1981 publication.

Surface Water Quality Monitoring in Oil Shale Development Areas

This project's technical objectives are to monitor the water quality in oil shale development areas not adequately covered by other monitoring programs.

Ground Water Research Program

A major problem facing the oil shale industry is measuring its impact on groundwater resources. Many investigations by government agencies, consulting firms and the oil shale industry predict that one in situ oil shale operation will physically affect over 100 square miles of groundwater. Although physical measurements have been estimated, potential chemical changes have been largely ignored. Long term groundwater contamination from oil shale operations is possible. Because groundwater and surface water, associated with major oil shale reserves, are closely related, physical or chemical alterations of one will affect the other. However, predictions based on specific mineralogical and water quality data should quantify groundwater quality variations associated with the oil shale industry.

In association with an in situ oil shale retorting operation, sample wells will be drilled and cores collected for mineralogy and ground water quality determinations. Backflood water quality (organic and inorganic) will be determined as well as egress aquifer mineralogy and absorptive capacity for backflood pollutants. The impact of the oil shale industry on ground water and related surface water resources will be assessed.

The results of these projects will provide local and state governments, the oil shale industrial community and involved federal agencies with information on important groundwater quality variations related to oil shale recovery. Research, conducted by grants, contracts, and interagency agreements, will 1) determine priority organic and inorganic pollutants having a potential impact on ground water, 2) determine the effectiveness of aquifer mineralogy in absorbing priority pollutants, 3) consider aquifer dispersion and mineralogical absorption, and 4) define area of influence and significance of pollutants' migration from retorting operations.

Adaption of Advanced Groundwater Monitoring Methodology to In Situ Oil Shale Retorting

Coal mining and the development of the immense reserves of oil shale in the semi-arid West pose major problems of groundwater pollution. Of special concern is the disposal of large amounts of spent oil shale which contain significant quantities of hazardous organic substances. An optimized anticipatory groundwater monitoring methodology for coal and oil shale sites is needed because it is impossible to clean up an aquifer once it has been contaminated.

The groundwater monitoring approach developed with earlier funding by GE Tempo (and accepted as official groundwater monitoring methodology by New Mexico and other states) is being adapted to the unique problems of groundwater contamination associated with coal and oil shale resources. This methodology is anticipatory in the sense that it determines contamination originating from a source and traveling through the unsaturated zone long before it reaches the water table (saturated zone). Conventional groundwater monitoring techniques focus on the saturated zone only.

Three areas (two for oil shale and one for strip coal mining) are being studied for the background conditions that will determine how the generalized monitoring methodology can be adapted as specific monitoring guidelines for these energy-related situations. The foundation studies mining practices, hydrology and geology, identification of pollutants, pollution sources, and pollutant infiltration and mobility in the subsurface. In addition, information on design and cost of monitoring installations and appropriate data management systems will be developed. Preliminary designs of cost-effective, step-by-step monitoring methods for specific sources will then be made.

Output/Rationale: The groundwater monitoring methodology developed by this effort will be presented in the form of a computer program. EPA Region VIII has expressed interest in this approach. The computer is accessible by phone hookup with an easily portable terminal. The systems program will operate as an expert panel, asking the user a series of increasingly more specific questions. The user, in turn, will interact with the computer, introducing site-specific data which will be integrated into a monitoring plan.

The preliminary monitoring designs for the test areas will require field validation and fine tuning before a final design can be acceptable. Similarly, the systematized version of the methodology for coal strip mining will need field verification.

3.4.4 Environmental Transport

The Mineralogy of Overburden as Related to Groundwater Chemical Changes in Strip Mining of Coal, In Situ Coal Gasification and In Situ Oil Shale Retorting

Investigators for this project propose to develop a method for predicting groundwater quality variations associated with coal strip mining, in situ coal gasification and in situ oil shale retorting to protect the quality of groundwater associated with energy production.

Cores from coal strip mining and in situ coal gasification and retorting were recovered from the surface down through the energy bearing resource. Wells were drilled, cored and sampled up gradient, within, and down gradient from the energy bearing resource. X-ray diffraction and X-ray fluorescence analyses were used to establish the mineralogy of the cores. Standard field and laboratory analytical methods were used to determine water composition. Water quality associated with detailed mineralogy was then studied. Factor analysis, thermodynamic calculations and graphical methods were used to interpret the data.

This project has successfully developed a technology capable of predicting groundwater chemical changes resulting from energy production.

Sorption Properties of Sediments and Energy Related Pollutants

Literature has been reviewed and laboratory investigations have been conducted to determine the strength and extent of energy related organic pollutant sorption by soils and sediments. Key variables controlling sorption processes have been identified and expressed in equations suitable for estimating partitioning behavior. Identifying the range of possible sorption behavior expected for energy-related pollutants in soils and sediments has provided a means for estimating partition coefficients in a wide variety of similar systems without additional measurements.

The approach involved an extensive literature review, published as a separate report, followed by a series of laboratory measurements which concentrated on variables expected to be important in predicting sorption behavior. Measurements included solubility, octanol/water partition coefficients and adsorption isotherms for 14 compounds on a set of 13 carefully selected and characterized sediments. Particular emphasis was placed on correlating compound solubility and octanol/water partition coefficients with sorption behavior on the sediments. Organic carbon content of the sediments was the property most directly related to their sorption behavior. Test compounds were selected to represent the predominant classes of pollutants associated with coal mining and processing activity. Sediments with wide ranges of organic carbon content, particle size distribution, and clay mineralogy were chosen.

Major accomplishments to date include a literature review published in August 1979 and several papers dealing with sorption behavior of individual compounds. The draft final report has been submitted and is presently under review. The most important results are predictive equations which give the sorption behavior as a function of either solubility or octanol/water partition coefficients.

Regional and Stratographic Variations of Oil Shale Mineralogy in Piceance and Uinta Basins

The existence of any significant regional mineralogical variations will be determined in this project, as well as potential leachate problems associated with oil shale ash, char and unaltered shale.

Following in situ oil shale retorting operations, new mineralogical surfaces will be exposed and available for leaching groundwater which will reenter the retort. The unanswered environmental question is: What is the quality, quantity, and regional significance of oil shale leachates from abandoned retorts?

Cores from the Piceance Basin have been collected for mineralogical examination. Oil shale samples, including shale ash, char, and unaltered shale from an in situ oil shale retort have been obtained for mineralogical examination and leachate quality and correlation studies.

Potential Air Pollution Effects of Oil Shale Activities in Piceance Basin

In response to Region VIII's request, the Energy and Air Division of OEPER initiated a major effort to study the potential air pollution effects of increased oil shale extraction activities in the Piceance Creek Basin, western Colorado.

The study will encompass:

1) Review and analysis of meteorological and air quality data previously obtained for the area.

2) Identification and characterization of primary (emitted) and secondary (transformed) air pollutants that may be detrimental to health, terrestrial and aquatic life and to visibility of Federal Class I Areas.

3) Modeling of the transport, transformation and dispersion of the primary and secondary pollutants from the source(s) to the environment.

The study will be undertaken by the Pacific Northwest Laboratory, Dr. Ronald Drake, Principal Investigator, under an existing EPA/DOE Interagency Agreement.

3.5 End Use

Advanced Combustion Systems for Stationary Gas Turbine Engines

The purpose of this project was to eliminate the need of water injection for NOx control while burning clean liquid and gaseous fuels and to develop control technology for GT's which may be required to burn high nitrogen fuels such as petroleum residue, shale oil or coal derived liquid fuels.

The contract was divided into four phases. The first phase compiled a series of combustor design concepts which had potential for meeting program goals. That effort was completed in mid-1976. The second phase of the program provided for bench scale evaluation of the concepts identified in Phase 1. That effort, completed in early 1978, identified a staged combustion concept called the "Rich Burn/ Quick Quench" (RBQQ) combustor and showed that NO_x emission 40 to 50% below the New Source performance standard could be achieved on both clean fuels and high nitrogen liquids. Phase III provided for scale-up of the technology to a size commensurate with a single can from a multican-25 MW electric machine. Phase III was completed in 1978. Phase IV, completed in October, 1979, provided for full scale experimental evaluation of the RBQQ combustor. NOx emissions of 65 ppm were recorded for the combustion of a 0.46% N residual shale oil and 80 ppm for a 1% N SRCII fuel. NSPS for both fuels is 125 ppm.

Development and Optimization of Low NO_x Burner Designs for Heavy Liquid Fuel Fired Package Boilers

Project investigators plan to develop low NO_x burner technology for heavy liquid fuel fired package boilers. Specifically, NO_x levels below 150 ppm for both firetube and watertube applications are sought.

The overall purpose of this project is to identify liquid fuel characteristics of NO_x control potential and to optimize low NO_x burners for future field application for boilers of both firetube and watertube design.

This program involves pilot scale testing at three scales. In the smallest scale (100,000 Btu/hr heat input) a spectrum of liquid fuels (petroleum, coal and shale derived) have been screened under a spectrum of combustion conditions. Results show that for "normal" combustion conditions NO_x increases almost linearly with fuel bound nitrogen content. NO_x levels exceeding 2000 ppm were measured while burning a 2.4% N shale oil. Those high NO_x levels can be significantly reduced through staged combustion. For the same 2.4% N shale oil staging reduced the NO_x to approximately 200 ppm. Further testing now indicates that even further reductions (approaching 100 ppm) may be possible. Larger scale testing (3.5 and 10 x 10^6 Btu/hr) are planned to incorporate the information learned in small scale to a practical new burner design.

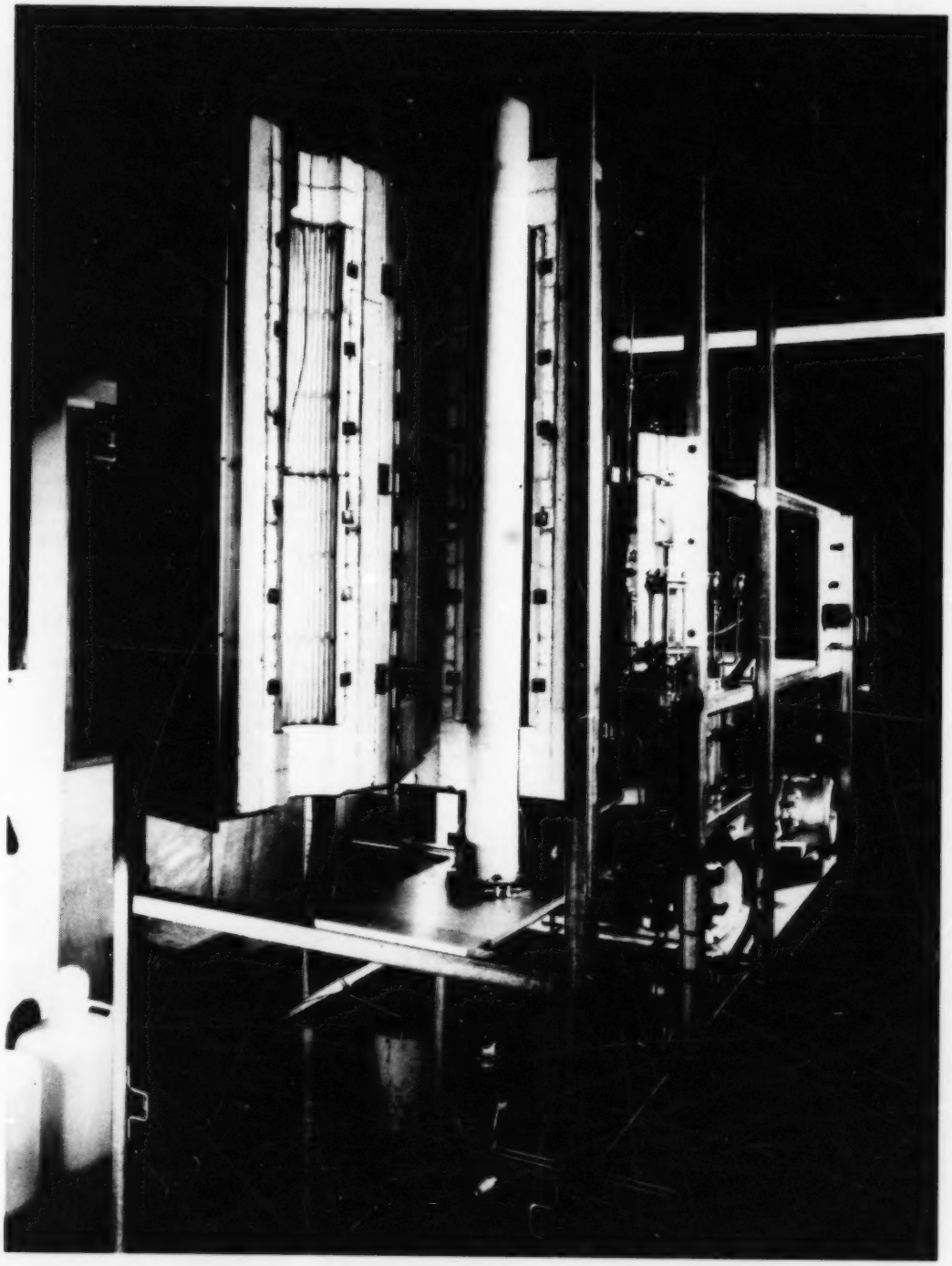

FIGURE 7. EXPERIMENTAL IN SITU OIL SHALE RETORT
(Courtesy of the Technical Information Division, University of California, Lawrence Berkeley Laboratory)

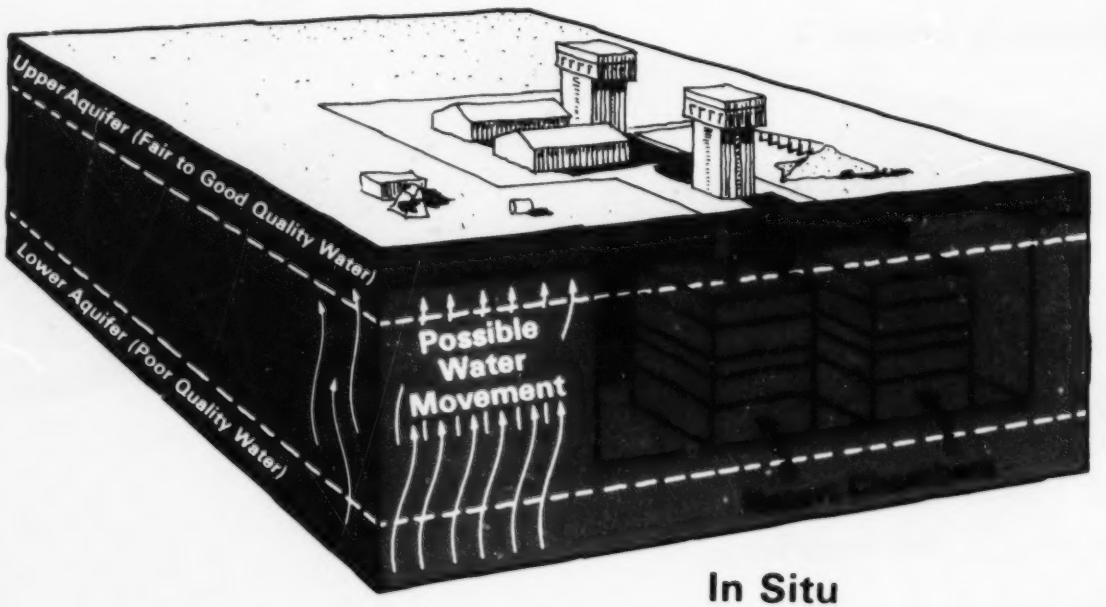

FIGURE 8. DIAGRAM SHOWS DETAILS OF THE IN SITU OIL SHALE EXTRACTION METHOD

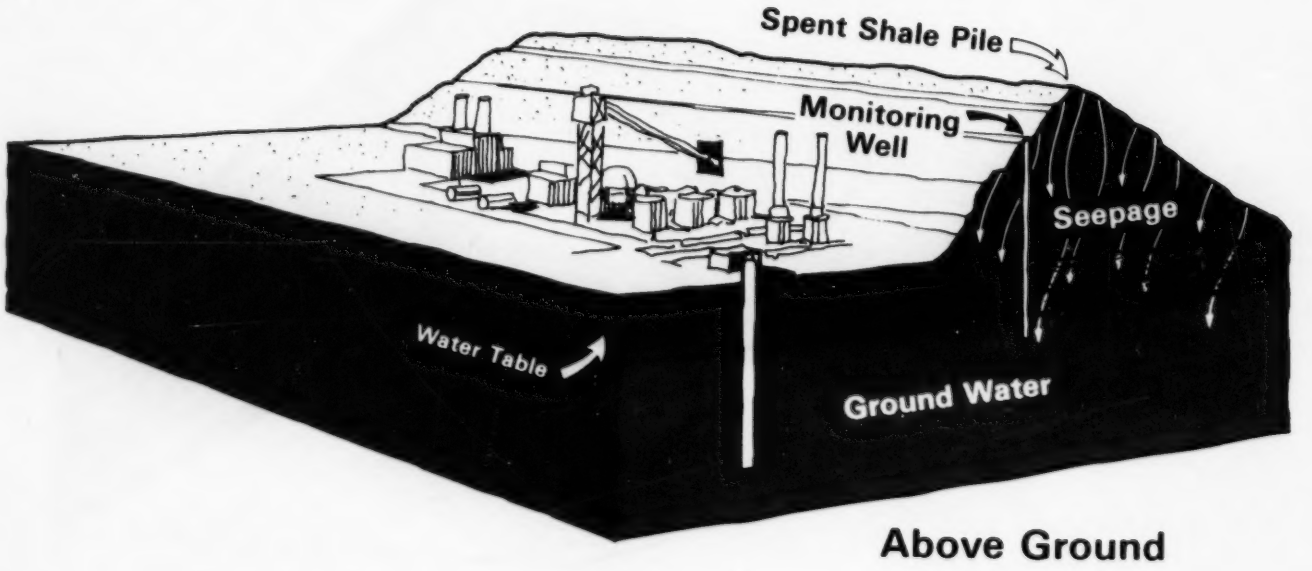

FIGURE 9. DIAGRAM SHOWS DETAILS OF THE ABOVE GROUND OIL SHALE EXTRACTION METHOD

TABLE 1. PROGRAM STATUS SUMMARY

Title	EPA Contact	Duration	Contractor	FY 79	FY 80	Total FY 79/80	Remarks
OVERALL ASSESSMENTS							
Environmental Perspective on the Emerging Oil Shale Industry	E. Bates (513) 684-4417	--	OSRG	121,000	70,000	191,000	
EPA/Industry Forum	K. Jakobson (202) 755-2737	-79	Geoenergy Corporation	73,000	0	73,000	
Who's Who in Oil Shale	W. McCarthy (202) 472-9444	-79	DRI	15,000	0	15,000	
Oil Shale Symposium: Sampling, Analysis and Quality Assurance	P. Mills (513) 684-4216	-79	DRI	22,000	0	22,000	
				231,000	70,000	301,000	
EXTRACTION AND HANDLING							
Develop Recommendations, Guidelines, and Criteria for Revegetation of Oil Shale Spoils on Semi-Arid Lands	R. D. Hill (513) 684-4410	75-81	USDA	100,000	100,000	200,000	Pass through--USDA
Water Quality Hydrology Affected by Oil Shale Development	E. F. Harris (513) 684-4417	75-80	CSU	26,000	0	26,000	
Vegetative Stabilization of Spent Oil Shale	E. Bates (513) 684-4417	75-81	CSU	44,000	40,000	84,000	
Laboratory Study of the Leaching Permeability of Spent Oil Shale	E. Bates (513) 684-4417	80-82	CSU	0	92,000	92,000	
Trace Element Analysis on Cores from the Naval Oil Shale Reserves	E. Bates (513) 684-4417	78-80	LBL	0	0	0	EPA Pass through funds to DOE
Leaching Characteristics of Raw Surface Stored Oil Shale	E. Bates (513) 684-4417	78-80	CSU	0	57,000	57,000	
Field Leaching Study of Raw Mined Oil Shale	E. Bates (513) 684-4417	80-83	CSU	0	67,000	67,000	

TABLE 1 (cont.)

Title	EPA Contact	Duration	Contractor	FY 79	FY 80	Total FY 79/80	Remarks
Air Emissions from Old In Situ Oil Shale Sites	E. Bates (513) 684-4417	-80	SAI	18,000	0	18,000	
Process Oil Shale Reclamation--Davis Gulch Study	E. Bates (513) 684-4417	80-85	Colony	0	350,000	350,000	
				188,000	706,000	894,000	
PROCESSING							
Environmental Characterization of Geokinetics' In Situ Oil Shale Retorting Technology	T. Powers (513) 684-4363	79-80	Monsanto	120,000	0	120,000	
Assessment of Oil Shale Wastewater Treatment and Control Technology	W. Liberick (513) 684-4363	79-82	Monsanto	330,000	400,000	730,000	
Air Pollution Investigations of Oil Shale Retorting: In Situ and Surface	R. Thurnau (513) 684-4363	-81	Monsanto	280,000	427,000	707,000	
H_2S/SO_2 Control Technology Study for Oil Shale Effluents	R. Thurnau (513) 684-4363	-81	Monsanto	97,000	82,000	179,000	
Analytical Methods Manual for Oil Shale Effluents	R. Thurnau (513) 684-4363	79-82	DRI	150,000	121,000	271,000	
Overview of the Environmental Problems of Oil Shale Development	R. Thurnau (513) 684-4363	79-80	DRI	100,000	152,000	252,000	
Distribution of As, Cd, Hg, Pb, Sb, and Se During In Situ Oil Shale Retorting	P. Mills (513) 684-4216	78-79	LBL	109,000	190,000	299,000	
Portable Zeeman Atomic Absorption Mercury Monitor	P. Mills (513) 684-4216	79-80	LBL	52,000	0	52,000	
Pollution Control Guidance Document for Oil Shale	E. Bates (513) 684-4417	-81	DRI	0	639,000	639,000	
				$1,238,000	$2,011,000	$3,249,000	

TABLE 1 (cont.)

Title	EPA Contact	Duration	Contractor	FY 79	FY 80	Total FY 79/80	Remarks
ENERGY RELATED PROCESSES AND EFFECTS							
Health Effects							
Repository for Alternate Energy Source Material for Toxicity Testing	D. Coffin (919) 541-2585	77-79	ORNL	207,500	0	207,500	Pass through funds to DOE
Morphological Variants in Damaged Sperm	D. Smith (301) 353-3682	75-80	LLL	60,000	60,000	120,000	Pass through funds to DOE
Detection of Early Changes in Lung Cell Cytology by Flow Systems Analysis Techniques	D. Smith (301) 353-3682	76-	LASL	50,000	50,000	100,000	"
Biological Screening Study of Shale Oil and H-Coal Liquefaction Operations	C. Nauman (202) 426-3974	79-81	ORNL	200,000	200,000	400,000	"
Detection of Oil Shale Related Mutagens Using Human Cell Cultures	C. Nauman (202) 426-3974	79-82	LASL	200,000	200,000	400,000	Pass through funds to DOE
In Vivo Screening for Gene Mutation in Mouse Germ and Somatic Cells	D. Smith (301) 353-3681	76-	ORNL	150,000	150,000	300,000	"
The Carcinogenic Effects of Petroleum Hydrocarbons on Selected Marine Estuarine Organisms	P. Schambra (919) 541-3467	-79	U. of Wash.	45,000	0	45,000	
Quantitative Mutagenesis Testing in Mammalian Culture Systems	D. Smith (301) 353-3681	76-80	LLL	75,000	75,000	150,000	Pass through funds to DOE
Development of Cytochemical Markers for Cell Transformation and Carcinogenesis	D. Smith (301) 353-3681	76-80	LLL	135,000	135,000	270,000	Pass through funds to DOE
Analysis of the Effects of Energy-Related Toxic Materials to Karyotype Stability in Mammalian Cells	D. Smith (301) 353-3681	76-	LASL	50,000	50,000	100,000	"

TABLE 1 (cont.)

Title	EPA Contact	Duration	Contractor	FY 79	FY 80	Total FY 79/80	Remarks
Effects of Products of Coal and Oil Shale Conversion on Cell Cycle Kinetics and Chromosome Structure	D. Smith (301) 353-3681	76-	LASL	50,000	50,000	100,000	Pass through funds to DOE
Mutagenicity Assay of Fractionated Coal Conversion and Oil Shale In Situ Retorting Products	D. Smith (301) 353-3681	75-	ORNL	135,000	135,000	270,000	Pass through funds to DOE
The Quantitative Evaluation of Hazardous Chemicals Using a Closed Aquatic Test System	D. Smith (301) 353-3681	76-	BNL	50,000	0	50,000	"
The Interaction of Chemical Agents Present in Oil Shale with Biological Systems	J. Bend (919) 541-3205	77-	NIEHS-RTP	0	0	0	Pass through funds to NIEHS
Development of Permanent Epithelial Cell Lines	D. Smith (301) 353-3681	76-	ORNL	60,000	60,000	120,000	Pass through funds to DOE
Development of an In Vitro Assay for Cocarcinogens of Coal/Oil Shale Derivatives	D. Smith (301) 353-3681	76-	UCLA School of Medicine	150,000	150,000	300,000	"
Influence of Diet on the Gastrointestinal Absorption of Energy-Related Metallic Pollutants	C. Nauman (202) 426-3974	-80	U. of Tenn.	77,000	77,000	154,000	
				$1,694,500	$1,392,000	$3,086,500	
Ecological Effects							
Effects of Pollutants Associated with Coal Gasification and Oil Shale Mining and Processing on the Aquatic Environment	L. Mueller or K. Biesinger (218) 727-6692	76-80	U. of Wyo.	50,000	50,000	100,000	Pass through funds to DOE
Chemical and Biological Characterization of Oil Shale Processing & Coal Conversion	L. Mueller (218) 727-6692	76-80	CSU	134,607	157,520	292,127	

TABLE 1 (cont.)

Title	EPA Contact	Duration	Contractor	FY 79	FY 80	Total FY 79/80	Remarks
Concentration of Well Waters from an Oil Shale Retorting Site for Biological Testing	P. Mills (513) 684-4216	-79	Monsanto	98,000	0	98,000	
Biological Guidelines for Integrated Environmental Monitoring for Mined Lands	H. Quinn (202) 653-5223	80-82	USFWS	150,000	150,000	300,000	Pass through funds to DOE
Developmental Markers and Reproductive Damage	C. Nauman (202) 426-3974	79-81	ORNL	289,000	300,000	589,000	Pass through funds to DOE
Develop Markers Reproductive-Teratological Damage	C. Nauman (202) 426-3974	79-81	ORNL	67,000	67,000	134,000	"
Develop Guidelines and Criteria for Use of Non-Mine Wastes as Soil Amendments on Oil Shale	R.D. Hill (513) 684-4216	-79	USDA Forest Service	24,000	0	24,000	
				$ 812,607	$ 724,520	$1,537,127	
Measurement and Monitoring							
Oil Shale Site Meteorological Data Analysis	T. Thoem (303) 837-5914	--	CDM Limnetics	0	0	0	
Air Quality and Surface Wind Monitoring in Colorado	T. Thoem (303) 837-5914	-80	CDH	10,000	0	10,000	
Upper Air Meteorological Data Collection	T. Thoem (303) 837-5914	-80	Aeromet	25,000	25,000	50,000	
Visibility Monitoring in Piceance Basin	T. Thoem (303) 837-5914	-79	OXY	0	0	0	
Monitoring the Impact of Oil Shale Extraction on Groundwater Quality	L. McMillion (702) 736-2969	-80	GE Tempo	150,000	130,000	280,000	
Energy Related Water Monitoring Data Integration	L. McMillion (702) 736-2969	-81	Dalton, Dalton Newport, Inc.	300,000	130,000	430,000	
Water Quality and Geochemistry of Shallow Aquifers of Piceance Creek, Colorado	F. Kilpatrick (703) 860-6846	-79	USGS	0	0	0	Pass through funds to USGS

TABLE 1 (cont.)

Title	EPA Contact	Duration	Contractor	FY 79	FY 80	Total FY 79/80	Remarks
Water Quality Monitoring on White River, Parachute Creek & Logan Wash in Oil Shale Areas of Western Colorado	F. Kilpatrick (703) 860-6846	-79	USGS	0	0	0	Pass through funds to USGS
Surface Water Quality Monitoring Techniques Assessment	W. Kinney (702) 736-2969 x353	-80	EMSL-LV	85,000	47,000	132,000	
Identification of Components of Energy-Related Waste and Effluents	A. Alford (404) 546-3525	78-79	GSRI	0	0	0	
Characterization of Dirty Aqueous Effluents from Energy Related Wastes & Effluents	G. Goldstein (301) 353-5348	78-81	Iowa St. U.	112,000	0	112,000	Pass through funds to DOE
Study of Raw Materials, Products and Residues of Coal Conversion and Oil Shale Processes for Possible SRM's: Oil Shale	C. Gravatt (301) 921-3775	75-79	NBS	115,000	0	115,000	Pass through funds to NBS
Western Energy Related Regional Air Quality Monitoring	D.N. McNeils (702) 736-2960	79-84	EMSL-LV	0	0	0	
Air & Water Monitoring Guidelines for Advanced Coal Conversion & Combustion Plants	R. Bateman (702) 736-2969	78-80	Dalton, Dalton Newport, Inc.	200,000	70,000	270,000	
Surface Water Quality Monitoring in Oil Shale Development Areas	R. Brennan (303) 234-3487	-80	USGS-WRD	8,900	11,553	20,453	Pass through funds to USGS
Ground Water Research Program	R. Newport (405) 332-8800	79-82	--	300,000	300,000	600,000	Pass through funds to DOE and various contractors
Adaption of Advanced Groundwater Monitoring Methodology to In Situ Oil Shale Retorting	L. McMillion (702) 736-2964	-82	GE Tempo	0	250,000	250,000	
				$1,305,900	$963,553	$2,269,453	

TABLE 1 (cont.)

Title	EPA Contact	Duration	Contractor	FY 79	FY 80	Total FY 79/80	Remarks
Environmental Transport							
The Mineralogy of Overburden as Related to Groundwater Chemical Changes in Strip Mining of Coal, In Situ Coal Gasification and Oil Shale Retorting	R. Newport (405) 332-8800	-79	CSMRI	170,000	0	170,000	
Sorption Properties of Sediments and Energy-Related Pollutants	D. Brown (404) 546-3592	-79	U. of Ill.	0	0	0	Project completed in 12-79
Regional and Stratographic Variations of Oil Shale Mineralogy in Piceance and Uinta Basins	R. Newport (405) 332-8800	-79	CSMRI	75,581	0	75,581	
Potential Air Pollution Effects of Oil Shale Activities in the Piceance Basin	D. Golomb (202) 426-0264	80-82	PNL	0	200,000	200,000	
				$ 245,581	$200,000	$ 445,581	
END USE							
Emission & Process Water Monitoring During Oil Shale Refining	W. McCarthy (202) 472-9444	-78	Navy	0	0	0	Pass through funds to Navy; project complete but no report
Advanced Combustion Systems for Stationary Gas Turbine Engines	W. Lanier (919) 541-2432	-79	Pratt & Whitney Aircraft	26,850	0	26,850	
Development and Optimization of Low NO_x Burner Designs for Heavy Liquid Fuel Fired Package Boilers	W. Lanier (919) 541-2432	-80	EERC	52,500	24,000	76,500	
				$ 79,350	$ 24,000	$ 103,350	

APPENDIX A
World Resources and History of Oil Shale Development

Oil shale deposits of varying size and quality are present in all continents. The potential yield from these extensive deposits has been estimated in hundreds of trillion barrels of oil. Interest in development of oil shale resources is not a recent concept. During the past 150 years, more than thirteen nations have developed oil shale industries. Factors such as primitive technology and unfavorable economic conditions contributed to the failure of a majority of these industries. Several nations developed or reactivated their oil shale industries during the years of World War II, a time of uncertain international trade and increased energy needs for national defense. Interest in oil shale diminished in the years following World War II. International trade and economic conditions returned to stable levels and oil shale processing became unprofitable.

Presently, interest in oil shale development is strong. The rapidly increasing costs of energy, specifically crude petroleum, are generating a favorable economic climate for oil shale development throughout the world. Advances in mining, process technology, and pollution control also add attraction to development of the resource.

USA

Oil shale deposits exist in two general areas of the U.S. Eastern Devonian oil shales are present in the Appalachian regions, and the leaner oil shales of the Green River Formation are found in the western states. Most development activities have centered around the expansive western reserves which cover approximately 11 million acres.

Western oil shale activities began in the late 1800s with several small scale experimental operations, but these primitive operations were only marginally successful and rarely produced more than several thousand barrels of oil.

Major industrial oil companies became interested in oil shale activities during the decade following World War I. Standard Oil of California, Union Oil of California, Texaco, and Cities Services began acquisition of oil shale properties during this period. Both laboratory and pilot studies were performed by these companies during the years following land acquisition.

The U.S. Bureau of Mines conducted experimentation with their N-T-U retort from 1925 to 1929. They also built and operated 6-, 25-, and 150 ton/day retorts at the Anvil Points site from 1950 to 1955.

A six company consortium funded experimentation at the Anvil Points facility during the mid-1960s. Development of the Anvil Points site continued in 1973 with the Paraho Oil Shale Project. Funding for this project was provided through a consortium of seventeen participating companies--Development Engineering Incorporated. This project was completed in 1978 with production of 100,000 barrels of shale oil under contract purchase to the U.S. Navy.

Recent testing has been conducted at the Paraho facility as part of an experimental/ demonstration agreement with the nation of Israel. Approximately 150 tons of Israeli oil shale were retorted in late 1979 in an effort to test the effectiveness of the Paraho technology in processing the Israeli shale. Characteristics and composition of the shale oil produced will help Israel in design of upgrading and refining processes.

Projected development plans for the Anvil Points Naval Oil Shale Reserve include a four year feasibility study for selection of process technology, a two year design and permitting phase, a four year construction phase, and a three year start-up phase with a final commercial production capacity of 50,000 BPCD (barrels per calendar day) by 1991. Because aboveground process technology will be used, the timetable for development to commercial scale may be shortened.

Mobil Oil Corporation has been involved with oil shale development in both the East and West since World War II. Mobil built and operated a pilot scale plant at Paulsboro, New Jersey, from 1943 to 1945. Mobil was also a member of the six member consortium which conducted experimentation at the Anvil Points facility in the mid-1960s. Mobil presently projects development of their privately owned land in the Piceance Basin with a six year permitting/construction phase for an aboveground process reaching a total production capacity of 100,000 BPCD by 1986.

The U.S. Department of the Interior initiated an Oil Shale Test Leasing Program

in 1968. Competitive bid sales on six land tracts in Colorado, Wyoming, and Utah began in January 1974. Two tracts in the Piceance Basin of Colorado (C-a, C-b) and two in the Uinta Basin of Utah (U-a, U-b) were leased during the following six months. The two Wyoming tracts did not draw acceptable bids and no leases were awarded.

Colorado tract C-a was leased to Rio Blanco Oil Shale, a joint venture of Gulf Oil and Standard Oil of Indiana. Original development plans included open pit mining with surface retorting. These plans have since been revised to project a Phase I operation by 1986 using a combination of surface and modified in situ retorting with a production capacity of 76,000 BPCD. Phase II commercial operations will produce a 135,000 BPCD total capacity by 1995.

Colorado tract C-b was leased in April 1974 to Ashland Oil, Inc., Atlantic Richfield Company, Shell Oil, Incorporated and The Oil Shale Corporation (TOSCO). By 1976, all but Ashland withdrew from the project. Occidental Petroleum Corporation entered the project in agreement with Ashland in late 1976. Ashland withdrew from the project in February 1979, leaving Occidental 100 percent leasehold position of the C-b tract. Occidental has conducted experimental modified in situ retorting burns on the tract several times in the past few years, and has projected development of the C-b tract to include a 65,000 BPCD modified in situ retorting process along with a 35,000 BPCD above ground retorting process for a total production capacity of 100,000 BPCD by 1990.

Utah lease tracts U-a and U-b will be jointly developed by the White River Oil Shale Corporation (Sohio, Sunoco, Phillips) using an above ground process and reaching a total production capacity of 90,000 BPCD by 1994. Actual development to commercial scale may occur more rapidly than reflected in present development plans.

Colony Development Corporation and The Oil Shale Corporation (TOSCO) have planned development of a commercial scale operation of 46,200 BPCD by 1986 using the TOSCO above ground retorting technology. The operation will be located in the Parachute Creek area of the Piceance Basin of Colorado.

TOSCO also plans development of its own 46,200 BPCD facility to be located in the Sand Wash area of Uinta Basin, Utah. TOSCO will use its own above ground technology to reach total commercial production capacity by 1986.

Union Oil plans modular development of their Long Ridge property in the Piceance Basin of Colorado. Union plans development of a 100,000 BPCD facility using above ground retorting technology by 1995.

Chevron Oil also plans modular development of their Long Ridge property in the Piceance Basin of Colorado. Projected total production capacity will be 100,000 BPCD by 1992.

Carter Oil jointly with Exxon presently plans a surface operation of 60,000 BPCD total production capacity by 1990. Development plans are contingent upon a federal land exchange agreement.

Superior Oil plans development of a multimineral process producing 12,000 BPCD of shale oil in addition to nahcolite and dawsonite recovery. Development plans are also contingent upon a federal land exchange agreement. Total production capacity is slated for 1987.

Geokinetics, Incorporated, is presently experimenting with horizontal in situ retorting methods on a pilot scale. Controlled pilot scale burns are currently being conducted on small sites in the Uinta Basin of Utah. These pilot burns have provided yields of thirty barrels of shale oil per day. Assuming continued favorable technological results from these pilot burns, Geokinetics plans development of ten small land sectors. Retort clusters will be manifolded in each sector with total production capacity for all ten sectors of approximately 50,000 BPCD reached by 1988.

Equity Oil is presently conducting pilot experiments in the Piceance Basin of Colorado with a unique recovery process. The Bx in situ Oil Shale Project involves use of steam injection for shale oil recovery, but the effectiveness of this novel approach is yet uncertain. Favorable results of pilot operations are necessary for projections of future development using the Bx process.

Projected development of the western U.S. oil shale resources could yield an estimated daily shale oil production of nearly one million barrels per day by 1995. Many individual development plans rely on federal economic incentives such as loan guarantees, tax credits, or accelerated depreciation schedules to be offered before development will begin. These incentives, in addition to possible direct federal assistance, may be provided through the currently proposed Energy Security Corporation of President Carter's synthetic

fuels package. Other federal agencies such as the U.S. Department of Energy (DOE) may also aid the emerging industry. DOE is currently issuing Program Opportunity Notices (PON) for demonstration of aboveground and advanced retorting technologies.

Interest in development of oil shale resources in the U.S. has been at high levels several times in the past 100 years, yet commercial development has never occurred. Economic factors have, in the past, made commercial development of oil shale unprofitable and therefore undesirable. Because of the rising costs of imported oil, synthetic fuels can now be produced at prices competitive with traditional energy products. Commercial shale development of western U.S. oil shale resources appears certain in the near future.

WORLD WIDE DEVELOPMENT

Australia

Oil shale deposits of high quality are found in many regions of Australia. Queensland and New South Wales contain rich oil shales associated with coal seams. These shales may yield 116 to 203 GPT (gallons per ton). Their areal distribution is rather small and thick overburden layers often cover these rich deposits.

Shale oil production took place in New South Wales from the mid-1860s through 1952. During this period, 70 GPT oil shales were retorted in Scottish Pumpherston-Fell type vertical kiln retorts. These operations produced a total yield of 700,000 barrels of oil shale during their many years of operation. Most of this total production occurred during wartime years. Operations were discontinued in 1952 in response to unfavorable economic conditions.

Australian firms of Southern Pacific Petroleum and Central Pacific Minerals have shown interest in shale oil production for the past six years. These firms jointly proposed a commercial operation which would process the high quality oil shale of the Rundle deposit located on the eastern coast of the continent, and initial proposals projected a Phase I operation producing approximately 23,000 BPD by 1981 using an above ground retorting process. Economic and engineering analyses have been conducted on Union, Lurgi-Ruhrgas, and Superior technologies. Phase II operations promote expansion to 250,000 BPD by 1986 using approximately 40 retorts. Current projections reflect a one year delay for both Phase I and II operations. Environmental impact assessments have been conducted to the satisfaction of the Australian government. Developers are presently securing financial arrangements for this $1.6 billion (U.S. dollars) project. Unhydrogenated shale oil produced would be used to fuel nearby power plants.

Brazil

Extensive deposits of medium to high grade oil shale are present in Brazil. These deposits have the capacity to support a large commercial oil shale industry. Brazilian oil shale may yield 18-53 gallons of shale oil per ton.

Many small scale experimental operations existed in Brazil during the late 1800s and early 1900s. Intensive research began in 1950 with several large research programs sponsored by the Brazilian government. These programs called for extensive exploration of oil shale resources throughout the country in addition to bench and pilot scale studies.

A site at San Mateus de Sol, Parana, was chosen for pilot plant construction after extensive exploration revealed reserves of approximately 200 million barrels. The 2,200 ton per day surface retorting facility began operation in 1973. The Petrosix retort used was designed by Cameron Engineers. The process generates power on site and produces high Btu fuel gas, LPG, elemental sulfur, and shale oil products. A nearby surface mining operation provides raw shale to the facility. This pilot scale demonstration facility has been successfully operating for several years.

Current development plans include increasing shale oil production of the Petrosix process at the San Mateus site to 25,000 BPD by 1983. Production will be further expanded to 50,000 BPD by 1985. Total cost for expanding the facility is estimated at $1.5 billion.

Bulgaria

Oil shale resources of Bulgaria have a total estimated potential yield of approximately 30 billion barrels of oil. Bulgaria has expressed interest in developing these extensive resources during the past ten years. In 1976, Bulgaria signed agreements with the USSR and West Germany (Lurgi Gmbh) to help develop a one million BPD shale oil industry by 1980. Original development plans called for expansion to 3 million BPD by 1990, but the status of development in Bulgaria is unknown at the present time.

England

Oil shales are found in thin seams throughout the Kimmeridge Clay formation of eastern England and the North Sea region. These oil shales may potentially yield 40 to 55 GPT. The shale seams are separated by barren clays with a low potential yield of 3 GPT. This layering of rich shale and barren clay has posed problems in mining and processing operations.

Kimmeridge Clay oil shales were used as coal substitutes several times during the 18th century. Interest in obtaining oil from these shales became apparent in the 19th century and experimentation was conducted during the later years of the century. Samples of Kimmeridge Clay oil shales were processed experimentally at the Scottish Lothian works. Several processing difficulties were encountered and the shale oil produced possessed high sulfur content.

The North Sea province is presently a widely developed source of crude petroleum reserves. Kimmeridge Clay may be the primary source rock of this hydrocarbon-rich region. Presently, difficulties in mining and processing shale of the area in addition to the existing large scale petroleum recovery of the North Sea region indicate that commercial development of English oil shale resources is not feasible at the present time.

France

Oil shale deposits exist in two primary regions of France, Autun and the Aumance basin. Shales with a potential average yield of 24 GPT are characteristic of these areas. Total reserves for the nation have been estimated (1974 World Energy Conference) at 237 megatonnes with a potential total yield of 1,740 million barrels.

France was the first nation to pioneer oil shale development, beginning commercial production as early as 1838. Scottish Pumpherston retorts were used from 1860 through the 1940s. Larger capacity French retorts were used for the remaining ten years of operation. Major products of these operations were diesel oil, gasoline, paraffin wax, and tar.

The industry was supported financially at various times by the French government. Despite these helpful measures, economic factors forced the closing of all operations by 1962. The oil shale industry of France presently remains dormant.

Germany

Germany has large oil shale deposits of several geologic ages. Total resources have been estimated at 311 megatonnes (1974 World Energy Conference), with an estimated potential yield of 2,280 million barrels. The oil shale averages approximately 16 GPT.

Development began in the late 1800s with small scale experimental surface retorting operations. The first large scale interest began in 1940 with initiation of oil shale operations at a portland cement plant in Dotternhausen. Meir-Grollman retorts were used in these operations.

In 1943, Lurgi began construction of an oil shale facility at Frommern. Construction was completed in 1947 and operations began at that time. Schweitzer retorts were used at this facility. Both Dotternhausen and Frommern facilities operated for ten years, with production ending in 1958.

Presently Germany uses oil shale for cement production and power generation. For the past few years government and industry have conducted bench scale studies on oil recovery from shale. Development plans are presently undefined, although development of an oil shale industry in Germany is a strong possibility in the near future.

Israel

Oil shale deposits exist in several areas of Israel. Extensive deposits exist in regions of the Negev desert. Recently, Israeli geologists have discovered large shale deposits near Arad, but their quality is extremely variable.

Israel imports virtually all of its energy sources in the form of fuel oil and coal for use in power generation. It is estimated that Israel could meet all of its energy requirements for up to twenty years through commercial development of oil shale resources. Israel has recently directed attention to the development of these resources as rising costs of imported energy make the option of energy self-sufficiency a desirable one.

In 1978 Israel sought U.S. aid in developing technologies suitable for commercial processing of Israeli oil shale. Israeli officials contacted such U.S. shale companies as TOSCO, Union Oil of California, Superior Oil Company, and Occidental Petroleum Corporation. In 1979, 150 tons of Israeli oil shale were retorted on a demonstration scale at the Paraho facility

at Anvil Points, Colorado. The shale was successfully retorted and the resulting shale oil product was returned to Israel for analysis and refining and upgrading technology design studies.

In 1978 the Israeli Energy Ministry allocated $500 million for development and construction of a 12,000 BPD facility to be located in the Negev desert region. The program has a ten year duration (1978-1988). Present plans call for surface mining operations to provide raw shale for the proposed surface retorting facility. Shale oil produced will be used to fuel nearby power plants.

Scientists at the Israeli Technion Institute in Haifa have recently experimented with a novel technology for extracting oil and gas from shale. This new approach uses a moderate strength laser beam inserted in shallow bore holes in the shale. The laser can be horizontally directed through use of mirrors. The laser ignites the shale and a small diameter pipe provides air to cool the mirrors and sustain combustion of the shale, and combustible gases and oil mists are collected at the surface opening of the bore holes. The method was developed by Rom, Schwartz, and Alterman, and has been successfully demonstrated with laboratory and small scale field studies. Equipment necessary for operation is of low cost and the whole process appears to be cost-effective. Current plans for the laser technology call for pilot plant studies with development of a laser recovery oil shale "field".

Israel Chemical, Ltd., a government owned company based in Tel Aviv, is also conducting preliminary studies on mining and retorting technologies for oil shale. Another area of their study is direct combustion of oil shale for power generation. Nesher, Ltd., an Israeli portland cement manufacturer, is also investigating applicability of oil shale in the production of cement.

People's Republic of China

Oil shale deposits exist in ten provinces of China. The Liaoning province of northern China and the Kwantung province of southern China both contain sizeable shale deposits which are presently supporting commercial development.

The Fushun deposit of the Liaoning province overlies thick coal deposits of the region, and the 450 foot thick shale deposit was first removed as a result of efforts to extract the rich underlying coal deposits. Commercial processing of oil shale first occurred at Fushun in 1926. This facility was operated by Japanese developers for many years and shale oil produced was used extensively by Japan during World War II. By 1970, the Fushun operations were producing 40,000 BPD of shale oil.

The facility is currently operating on a large scale, using more than six vertical retorts. A large surface mining operation provides raw shale to the facility in addition to mining approximately 3.6 million tons of coal annually. Shale oil produced is refined in small neighboring plants.

The Maoming shale oil producing field is located in the Kwantung province of southern China. Operations at the Maoming site are similar to those at Fushun, although coal production is absent from Maoming. Annual shale oil production of this facility is approximately 570,000 barrels.

Scotland

Oil shale deposits exist in various regions of Scotland. Devonian shales are present in northern Scotland but these deposits appear to have limited commercial value. Carboniferous shales have been discovered in central and southern regions of the country, and the Lothian deposit in central Scotland is the largest known deposit in western Europe.

Development of oil shale processing operations began in Scotland in the mid-1800s. Early operations used horizontal batch retorts which were subsequently replaced by vertical batch retorts of higher efficiency. A semi-continuous vertical retort was developed in 1882 and used in several operations through 1894. In 1894, Bryson, Jones, and Fraser developed the continuous 12 ton per day Pumpherston retort which was used extensively in Scottish shale works for more than one half century. Oil shale operations of several nations also incorporated Pumpherston type retorts in their facilities.

Mining methods used during the 100-year Scottish oil shale industry were of two types. Underground inclined shaft mining was commonly used for extraction of shale from angular seams. Surface mining was also used to a limited extent. Approximately 140 million tons of shale were extracted during the life of the oil shale industry. Mining efforts were extremely effective as less than four weeks of the United Kingdom oil needs could be met by recovering and processing the remaining reserves.

Maximum shale oil production took place in 1913 with total production estimated at 4,400 BPD. Major products included diesel oil and gasoline, although sizable quantities of tars and waxes were also produced. The oil shale industry of Scotland is no longer operative. Production ended in 1963 due to depletion of resources and unfavorable economics.

South Africa

Significant oil shale deposits exist in two provinces of South Africa, Natal Province and Transvaal Province. Shales of the Natal Province occur in beds less than one foot thick. These shales are of high quality with maximum attainable yields as high as 96 GPT. The Transvaal Province contains torbonite oil shales which may yield as much as 37 percent oil from Fischer Assay methods.

Commercial development of the Natal Province oil shales began in 1935 in the region of Ermelo. The Ermelo facility operated successfully for many years until depletion of shale resources forced its closing. Major products from these operations were gasoline and tars. Oil shales of the Transvaal Province are currently being used locally as fuels.

Spain

Oil shale deposits of limited size exist in Spain. Total reserves for the nation have been estimated at 6 megatonnes (1974 World Energy Conference). Shale quality is relatively high, ranging 30-50 GPT.

Despite the presence of small scale resources, commercial oil shale development begin in Spain in 1922. Commercial operations existed for 43 years at a site 120 miles south of Madrid at Puertollano. Scottish Pumpherston retorts were used in these operations. Production levels as high as 14,000 BPD were attained in 1958 (DeGolyer and MacNaughton, 1971). Major products were diesel oil and gasoline. The present status of these operations is not known.

Sweden

Oil shale deposits exist throughout Sweden. Most deposits are of marine origin with an average quality of approximately 14 GPT. Oil shale development began during the 1920s with construction of an experimental plant at Kinnekulle. The plant operated successfully for several years on a small scale while technologies were being modified and improved, but economic pressures finally forced closing of the facility.

Oil shale production began again in the 1940s with construction and operation of a larger government funded facility at Kvarntorp. Operations at this site involved open pit surface mining, surface and in situ retorting, sulfur recovery, refining facilities, and on site steam power generation. Operations continued until 1963 when economic factors also forced abandonment of this facility. Gasoline, fuel oil, kerosene, and gas were major products of these operations. Maximum daily shale oil production was attained in 1958 with an approximate production level of 33,000 BPD.

Thailand

Oil shale resources of Thailand have only recently been explored. Extensive deposits of medium to high grade shales exist in the northern regions, but these resources have not been developed to date.

Recently Thailand has sought technical advice in planning development of an oil shale processing facility. Missions were sent to the People's Republic of China in an unsuccessful effort to view the Maoming shale oil field in Kwantung province. Contacts have also been made with U.S. oil shale concerns.

Thailand presently imports approximately 150,000 barrels of crude oil daily to meet nearly 80 percent of daily national energy needs, but development of a commercial scale oil shale processing facility could greatly reduce or possibly eliminate this costly importation of foreign oil for a period of more than twenty years. Oil shale production costs would be economically competitive, if not advantageous, compared to present imported crude petroleum costs.

Current oil shale development plans are still in formative stages although development seems certain in the near future.

U.S.S.R.

Oil shale activities in the U.S.S.R. have historically occurred in the northeastern regions of Estonia. These regions contain extensive shale deposits but lack other energy sources such as crude petroleum and coal deposits. Average potential yields of Estonian shales, or Kukersite, fall within a range of approximately 30-45 GPT.

Development of Estonian oil shale resources began in 1925 with construction of a 200 ton per day plant for production

of low Btu town gas. Pintsch-type retorts were used in these operations. The 1930s brought use of horizontal tunnel ovens with capacities of up to 400 tons. Gas and oil were recovered from these operations. Externally heated Davidson rotary retorts were also used at this time. Total production by the mid-1930s was approximately 3,700 BPD (Degolyer and MacNaughton, 1971).

In the 1940s war disrupted Estonian shale operations when the Germans occupied the region. Russia regained control of the area in 1944 and expanded the industry during the following years. Production levels reached approximately 245,000 BPD in 1958. This impressive level reflects energy equivalent estimates for 60% of total raw shale usage as solid fuel for power generation.

Extensive development and demonstration programs began in the 1960s. Tunnel ovens and rotary retorts were phased out during these efforts. New technologies for production of tar and gas petrochemicals feedstocks were explored in the 1960s and 1970s.

Presently more than 30 chemicals are being produced from oil shale kerogen. Shale fuels many large power plants near the Baltic Sea, providing 80% of Estonian energy needs. The U.S.S.R. presently mines more than 35 million tons of oil shale annually, which supplies 1% of Soviet national energy needs.

APPENDIX B
Glossary of Terms

Absorption - The taking up of matter in bulk by other matter, as in dissolving of a gas by a liquid; passage of a chemical substance through a membrane.

Adsorption - The surface retention of solid, liquid, or gas molecules, atoms, or ions by a solid or liquid, as opposed to absorption, the penetration of substances into the bulk of the solid or liquid.

Aquifer - A permeable body of rock capable of yielding quantities of groundwater; a subsurface zone that yields economically important amounts of water to wells.

Assay - Qualitative or quantitative determination of the components of a material.

Atomic Absorption Spectroscopy - Measurement of components of a substance through interpretation of spectra arising from absorption of electromagnetic radiation by atoms.

BACT - (Best Available Control Technology). The level of pollution control technology that a new or modified major pollution source, which is located in an area designated as meeting ambient air quality standards, must install.

Barrel - The unit of liquid volume for petroleum equal to approximately 158 liters (42 gallons).

Bioassay - Determination of the relative effective strength of a substance by comparing its effect on a test organism with that of a standard preparation.

Carcinogen - Any agent that incites development of a malignancy.

Cascade Sampler - A low-speed impaction device for use in sampling both solid and liquid atmospheric suspensoids: Consists of jets (each of progressively smaller size) and sampling plates working in series and designed so that each plate collects particles of one size range.

Chromatin - The deoxyribonucleoprotein complex forming the major portion of the nuclear material and chromosomes.

Clastogen - Any agent that produces chromosomal aberrations.

Coal Liquefaction - The process of preparing a liquid mixture of hydrocarbons by destructive distillation of coal.

Columnar Cell - Composed of tall, narrow somewhat cylindrical or prismatic epithelial cells.

Consent Decree Pollutants - A list of sixty-five (65) toxic chemicals for which EPA is required to develop limitations and standards. For some rule-making purposes EPA has redefined the list of 65 broad chemicals/chemical classes to 129 more specific chemicals.

Criteria Pollutants - Those pollutants for which EPA has published including ambient air quality standards and for which state implementation plans exist (including SO_x, CO, NO_x, O_3, hydrocarbons, particulates, lead).

Cytochemical - Any of the complex protein respiratory pigments occurring within plant or animal cells.

Cytology - A branch of biology dealing with the structure, behavior, growth, and reproduction of cells and the function and chemistry of cell components.

Cytotoxin - A substance, such as a toxin or antibody, that inhibits or prevents the functions of, or destroys cells.

Devonian Deposit - A geological formation deposited during the Devonian period some 350 to 400 million years ago.

DNA - Deoxyribonucleic acid; any of various nucleic acids that yield deoxyribose as one product of hydrolysis, are found in nuclei and genes, and are the molecular basis of heredity in many organisms.

Electrophoresis - The movement of charged colloidal particles through the medium in which they are dispersed, under the influence of an applied electric potential.

Enzyme - Any of a number of catalytic proteins produced by living cells and having a specific action in mediating and promoting chemical processes.

Epididymal - Pertaining to the elongated mass of convoluted efferent tubes at the back of the testis.

Epithelial - Pertaining to the tissues which cover free surfaces (skin) or lining of body cavities and ducts.

Epithelium - A primary animal tissue covering the free surface that lines a tube or cavity, consisting of one or more layers of cells forming a sheet practically unbroken by intercellular substance, and either smoothly extended or much folded on a basement membrane and compacted.

Esterase - Any group of enzymes that catalyze the synthesis and hydrolysis of compounds formed by the elimination of water and the bonding of an alcohol and an organic acid (esters).

Eukaryote - An organism composed of one or more cells with well-defined nuclei.

Evapotranspiration - Discharge of water from the earth's surface by evaporation from lakes, streams, and soil surfaces and by transpiration from plants. Also known as fly-off.

Exfoliation - The separation of tissue in thin layers.

Flow Microfluorometry (FMF) - A method of chemical analysis using an optically enlarged fluorescent screen which measures movement of a sample through a flow chamber. The sample is exposed to radiation of one wavelength, absorbs this radiation and reemits radiation of the same or longer wavelength in about 10^{-9} second; the intensity of the reemitted radiation is almost directly proportional to the concentration of the fluorescing material.

Fugitive Dust - Any form of particulate which is transported as a result of wind or mechanical operations. Typical mechanical generators are vehicles, crushing machines and earth movers.

Gas Chromatography - A separation technique involving passage of a gaseous moving phase through a column containing a fixed adsorbent phase; used principally as a quantitative analytical technique for volatile compounds.

Gel Permeation Chromatography - Analysis by chromatography in which the stationary phase consists of beads of porous polymeric material such as a cross-linked dextran carbohydrate derivative sold under the trade name sephadex; the moving phase is a liquid.

High Pressure Liquid Chromatography - A separation technique employing a pressurized solvent as a moving phase through a column containing a solid support.

High-Volume Sampler - A sampling device consisting of a filter and a high volume air pump used for the quantitative collection of airborne particulate materials.

Hydrocarbon - One of a very large group of chemical compounds composed only of carbon and hydrogen; the largest source of hydrocarbons is from petroleum crude oil.

In Situ - In the original location.

In Vitro - Pertaining to a biological reaction taking place in an artificial apparatus.

In Vivo - Pertaining to a biological reaction taking place in a living cell or organism.

Karyotype - The normal diploid or haploid complement of chromosomes, with respect to size, form and number, characteristic of an individual, species, genus, or other grouping.

Kerogen - The complex, fossilized organic material present in sedimentary rocks, especially in shales.

Lavaging - The washing out of an organ.

Leaching - The dissolving, by a liquid solvent, of soluble material from its mixture with an insoluble solid; a separation based on mass transfer.

Leukocyte - A colorless, ameboid blood cell having a nucleus and granular or non-granular cytoplasm; any of the white or colorless nucleated cells that occur in blood.

Macroinvertebrate - A large animal lacking an internal skeleton.

Mass Spectrometry - An analytical technique for identification of chemical structures, determination of mixtures, and quantitative elemental analysis, based on sending a beam of ions through a combination of electric and magnetic fields so arranged that the ions are deflected according to their masses.

Mesozoic Deposit - A geological formation deposited during the Mesozoic era some 60 to 230 million years ago.

Mississippian Deposit - A geological formation deposited during the Mississippian period approximately 310 to 345 million years ago.

Mutagen - An agent that raises the frequency of mutation above the spontaneous rate.

New Source Performance Standards (NSPS) - Guidelines set for new industries ensuring that ambient standards are met and limiting the amount of a given pollutant a stationary source may emit over a given time. Standards apply to facilities built since August 17, 1971.

Oil Shale - A finely layered rock that contains kerogen and from which liquid or gaseous hydrocarbons can be distilled. Also known as kerogen shale.

Permian Deposit - A geological formation deposited during the Permian period approximately 230 to 280 million years ago.

Phagocytic Activity - The process of engulfing and carrying particles into the cytoplasm of an ameboid cell.

Priority Pollutants - See Consent Decree Pollutants.

Prokaryote - A primitive nucleus, where the DNA-containing region lacks a limiting membrane.

Quality Assurance - A system for integrating quality control planning, assessment, and improvement of all work dealing with quantitative measurements.

RNA - Any of various nucleic acids that contain ribose and uracil as structural components and are associated with the control of cellular chemical activities.

Retorting Operation - Process of extracting shale oil from the raw shale by heating.

Sorption - A general term used to encompass the processes of adsorption, absorption, desorption, ion exchange, ion exclusion, ion retardation, chemisorption, and dialysis.

Spent Shale - (Retorted Shale) The shale residue after the shale oil has been extracted.

Teratogen - An agent causing formation of a congenital anomaly or monstrosity.

Tertiary - The older major subdivision (period) of the Cenozoic era, extending from the end of the Cretaceous to the beginning of the Quaternary, from 70,000,000 to 2,000,000 years ago.

X-ray Fluorescence - Emission of the characteristic x-ray line spectrum of a substance upon its exposure to x-rays. A method of analysis based on this type of spectral emission.

APPENDIX C
Glossary of Abbreviations

AOSO	Area Oil Shale Office USGS
BNI/PNL	Battelle Memorial Institute Pacific Northwest Laboratories Richland, Washington (under DOE)
BNL	Brookhaven National Laboratory, Brookhaven, New York
CEQ	Council for Environmental Quality
CDH	Colorado Department of Health
CSMRI	Colorado School of Mines Research Institute
CSU	Colorado State University
DOE	Department of Energy
DRI	Denver Research Institute
ECTD	Emission Control Technology Division, Office of Air, Noise and Radiation EPA, Ann Arbor, Michigan
EERC	Energy and Environmental Research Corporation Santa Ana, California
EMSL-Ci	Environmental Monitoring and Support Laboratory EPA, Cincinnati, Ohio
EMSL-LV	Environmental Monitoring and Support Laboratory EPA, Las Vegas, Nevada
EMSL-RTP	Environmental Monitoring and Support Laboratory EPA, Research Triangle Park, N.C.
EPA	Environmental Protection Agency
ERIC-Ci	Environmental Research Information Center, EPA Cincinnati, Ohio
ERL-Athens	Environmental Research Laboratory, EPA Athens, Georgia
ERL-Duluth	Environmental Research Laboratory, EPA Duluth, Minnesota
ERL-GB	Environmental Research Laboratory, EPA Gulf Breeze, Florida
HERL-RTP	Health Effects Research Laboratory, EPA, Research Triangle Park, N.C.
HERL-Ci	Health Effects Research Laboratory, EPA Cincinnati, Ohio
IERL-Ci	Industrial and Environmental Research Laboratory EPA, Cincinnati, Ohio
IERL-RTP	Industrial Environmental Research Laboratory, EPA Research Triangle Park N.C.
LASL	Los Alamos Scientific Laboratory, Los Alamos, New Mexico (Under the DOE)
LBL	Lawrence Berkeley Laboratory Berkeley, California (Under the DOE)
LETC	Laramie Energy Technology Center Laramie, Wyoming (Under the DOE)
LLL	Lawrence Livermore Laboratory Livermore, California (Under the DOE)
NBS	National Bureau of Standards
NIEHS	National Institute of Environmental Health Sciences Research Triangle Park, N.C.
NIOSH	National Institute of Occupational Safety and Health
NIH/NIEHS	National Institute of Health National Institute of Environmental Health Studies
OEET	Office of Environmental Engineering and Technology

OEPER	Office of Environmental Processes and Effects Research
ORD	Office of Research and Development, EPA (EPA/ORD)
ORNL	Oak Ridge National Laboratory, Oak Ridge, Tennessee (Under the DOE)
OSM	Office of Surface Mining
OSRG	Oil Shale Research Group
RCRA	Resource Conservation and Recovery Act
R.S. KERR	Robert S. Kerr Environmental Research Laboratory Ada, Oklahoma
SAI	Science Applications Incorporated
TOSCO	The Oil Shale Corporation
UCLA	University of California at Los Angeles
UNLV	University of Nevada at Las Vegas
USBM	U.S. Bureau of Mines, Department of Interior
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service Department of Interior
USGS	U.S. Geological Survey Department of Interior

APPENDIX D
A General Bibliography on Oil Shale

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